THE PRODUCTION ENGINEER

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

DECEMBER 1960

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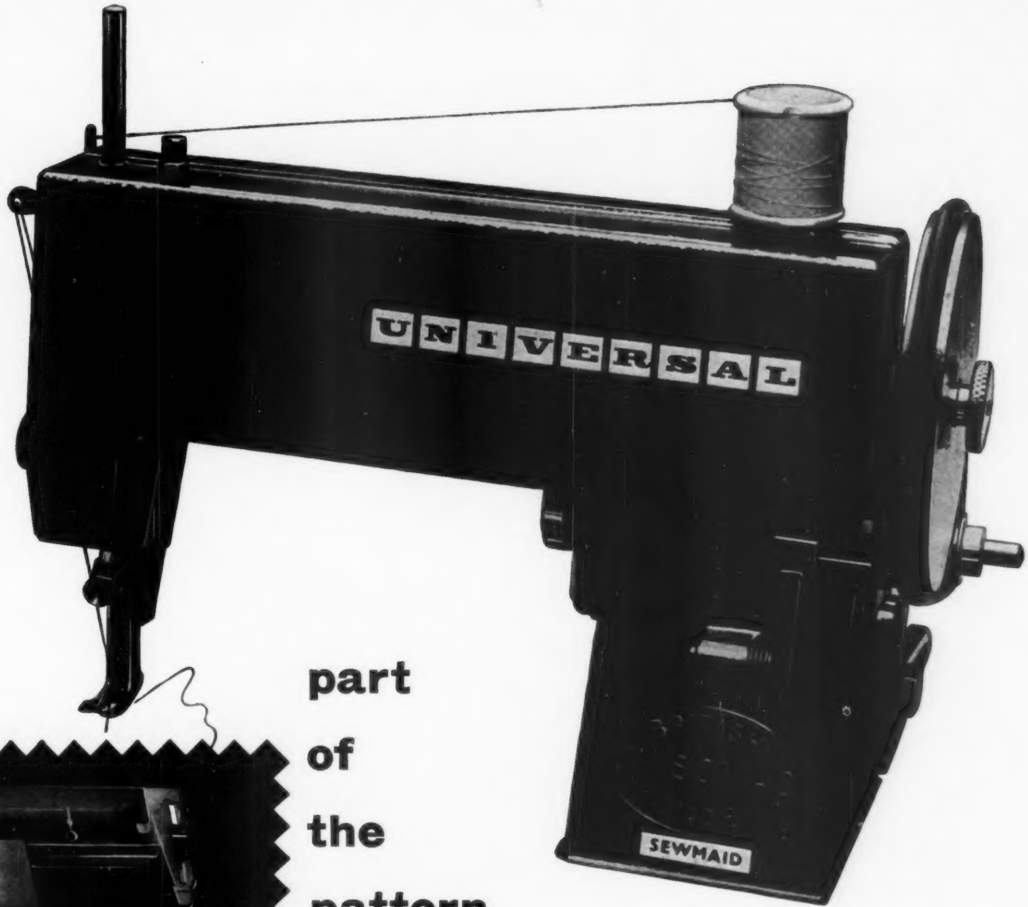
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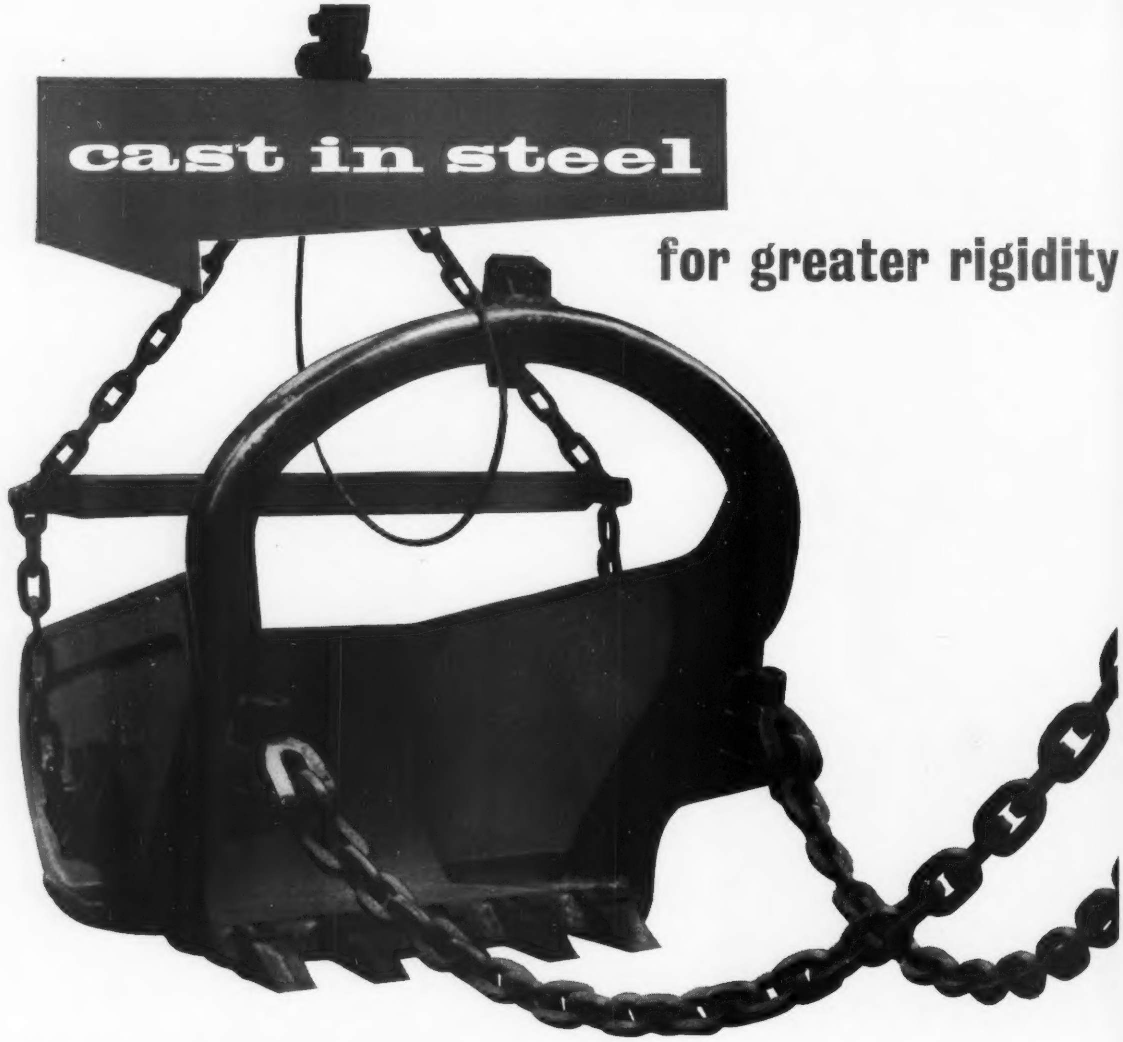
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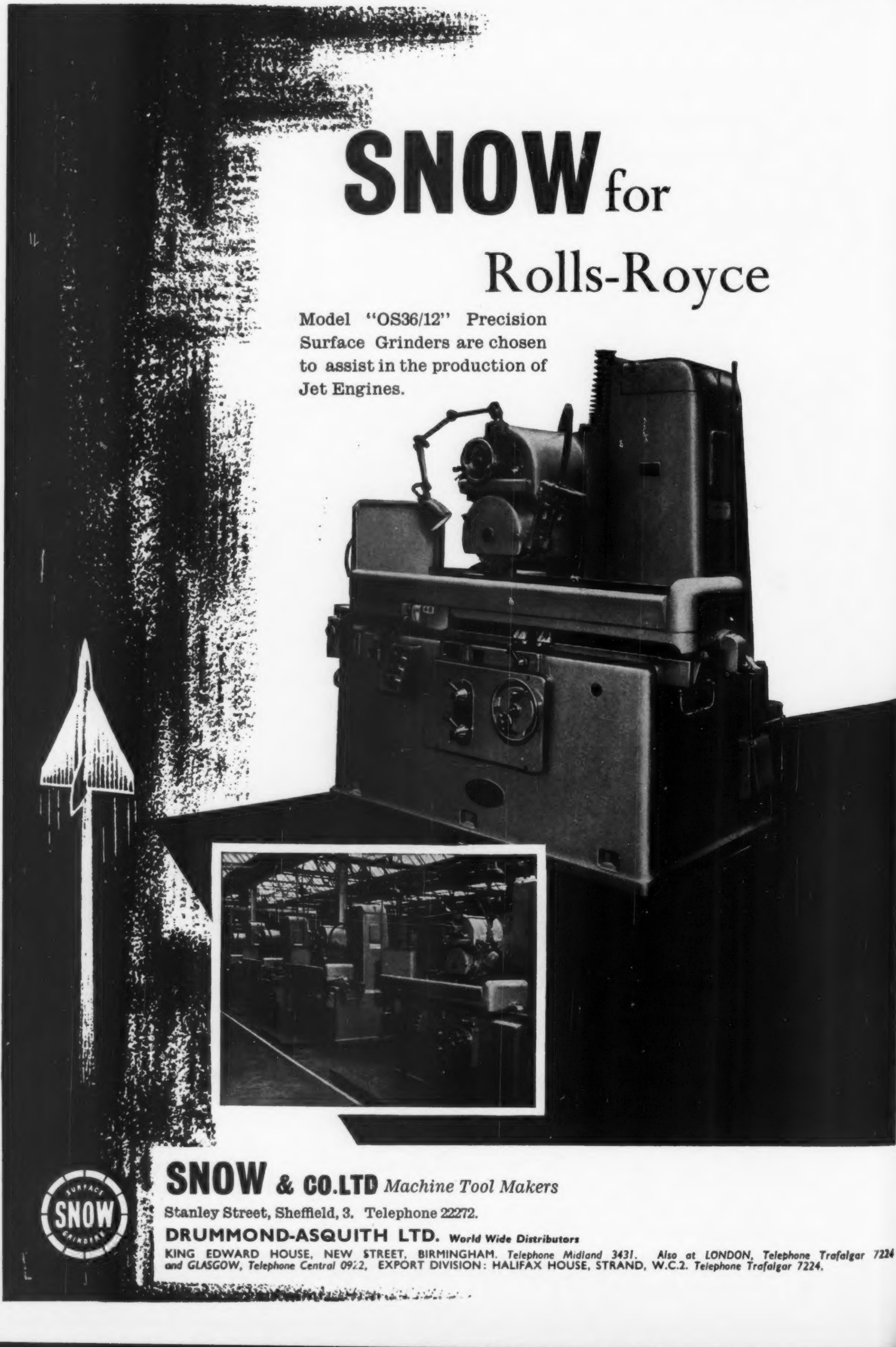
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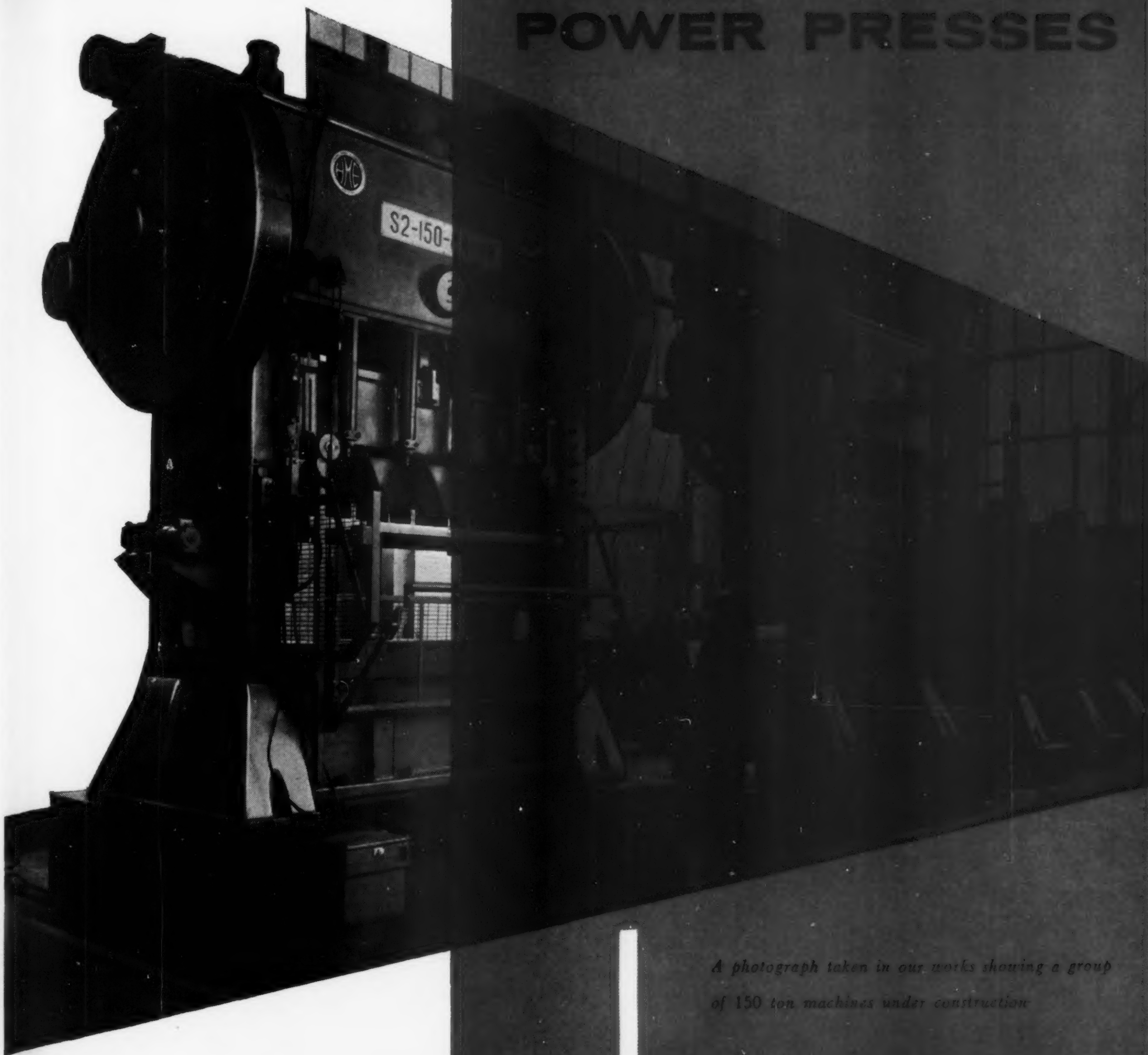

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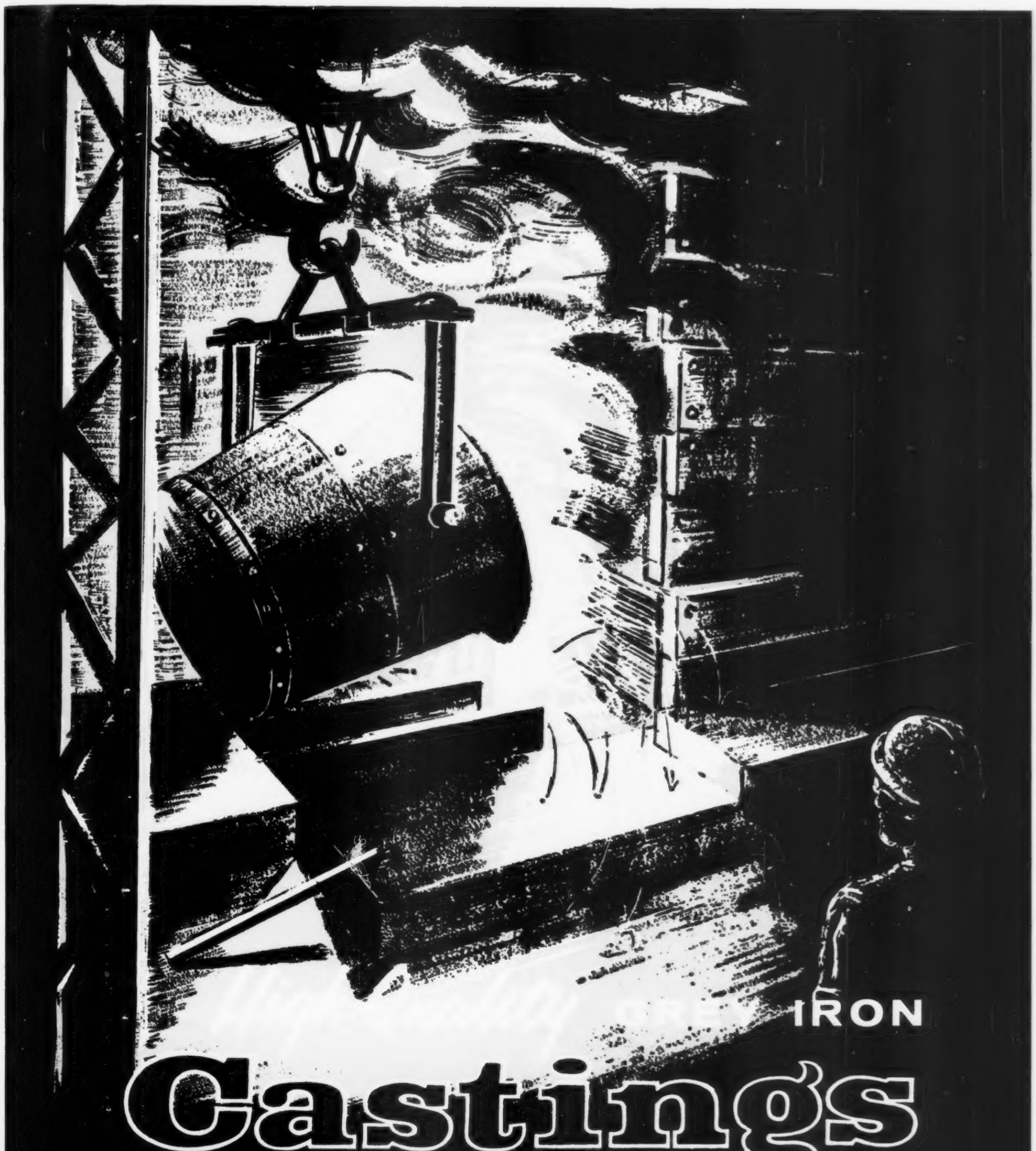
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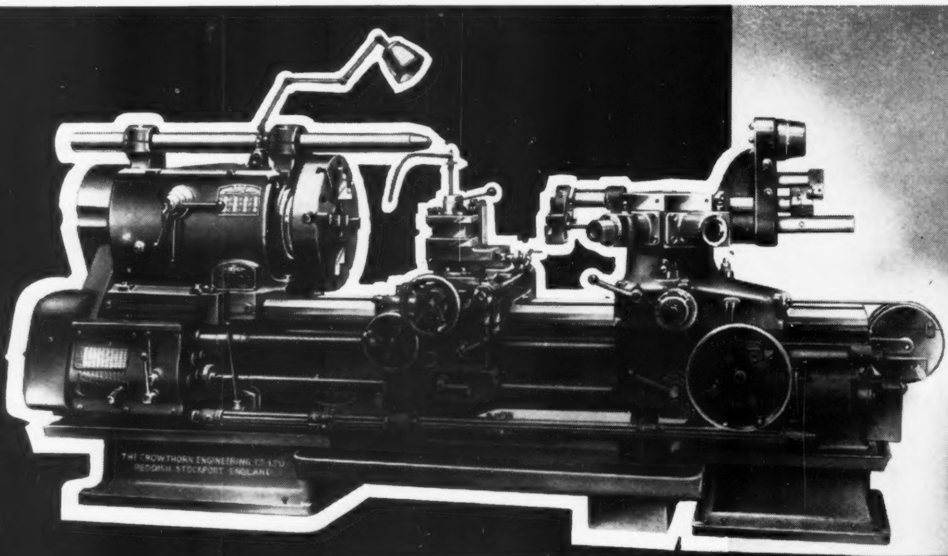

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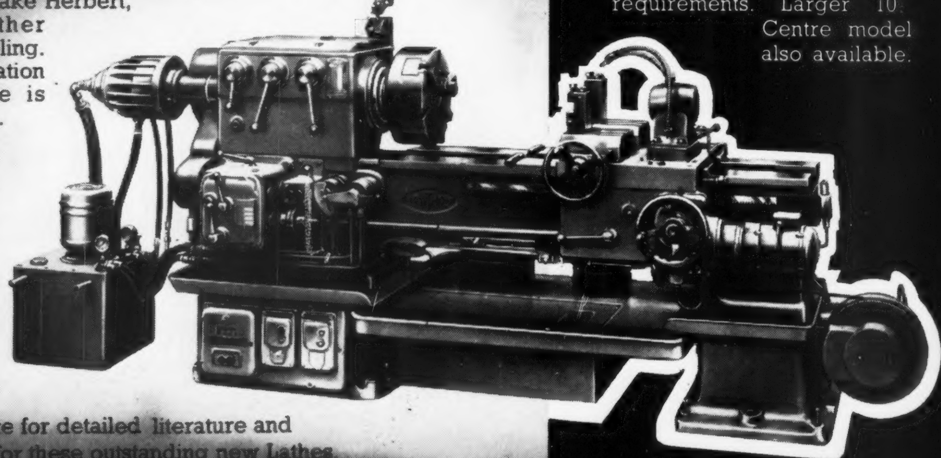

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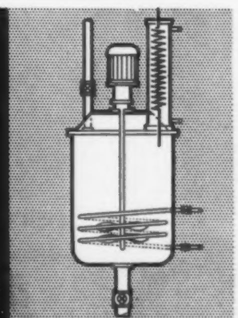

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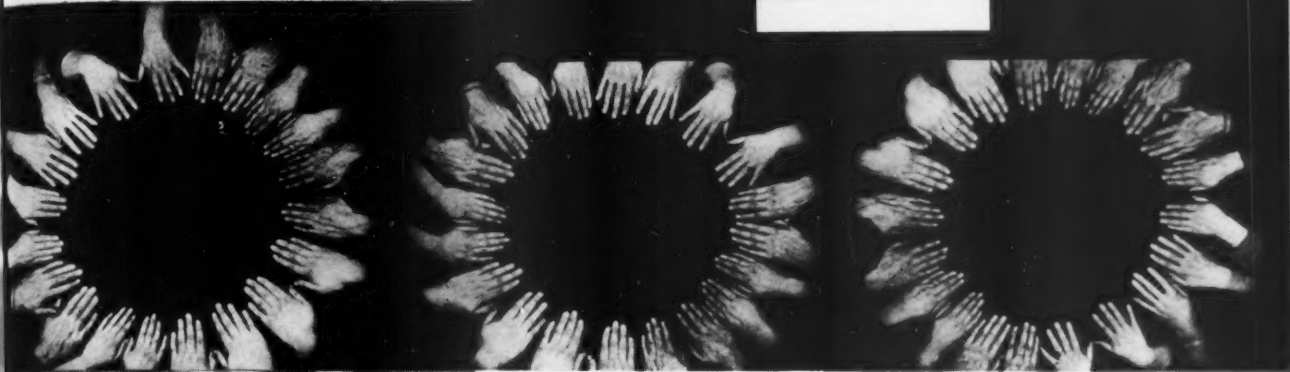

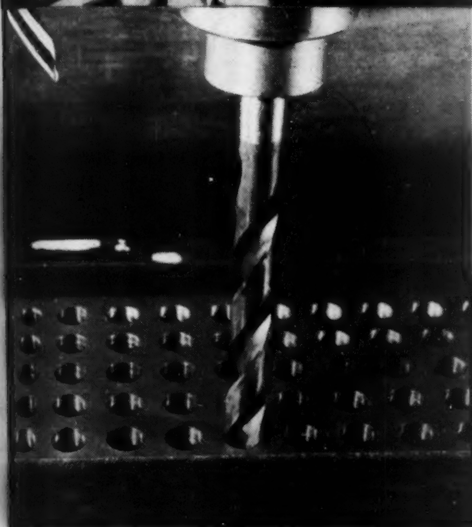

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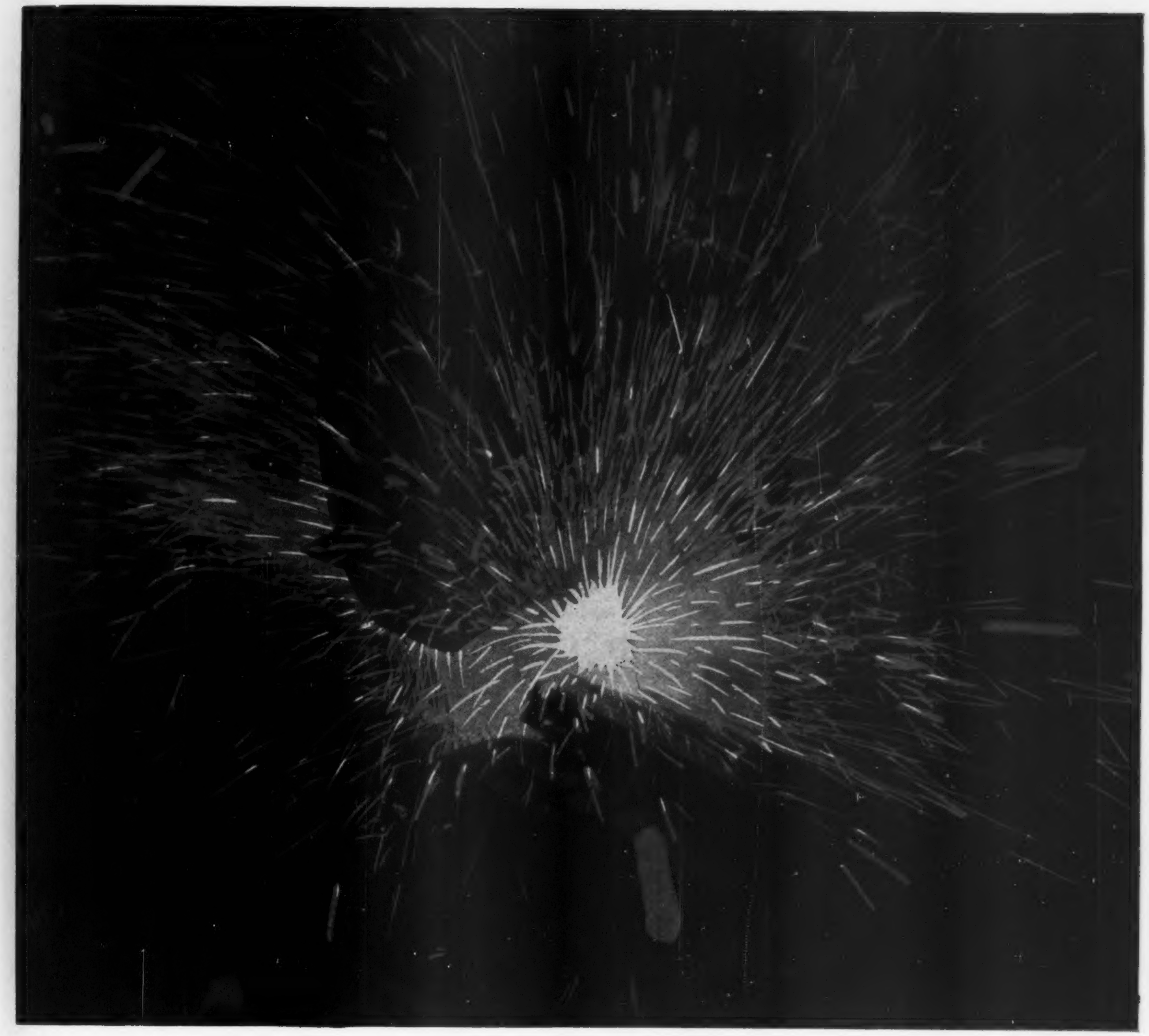


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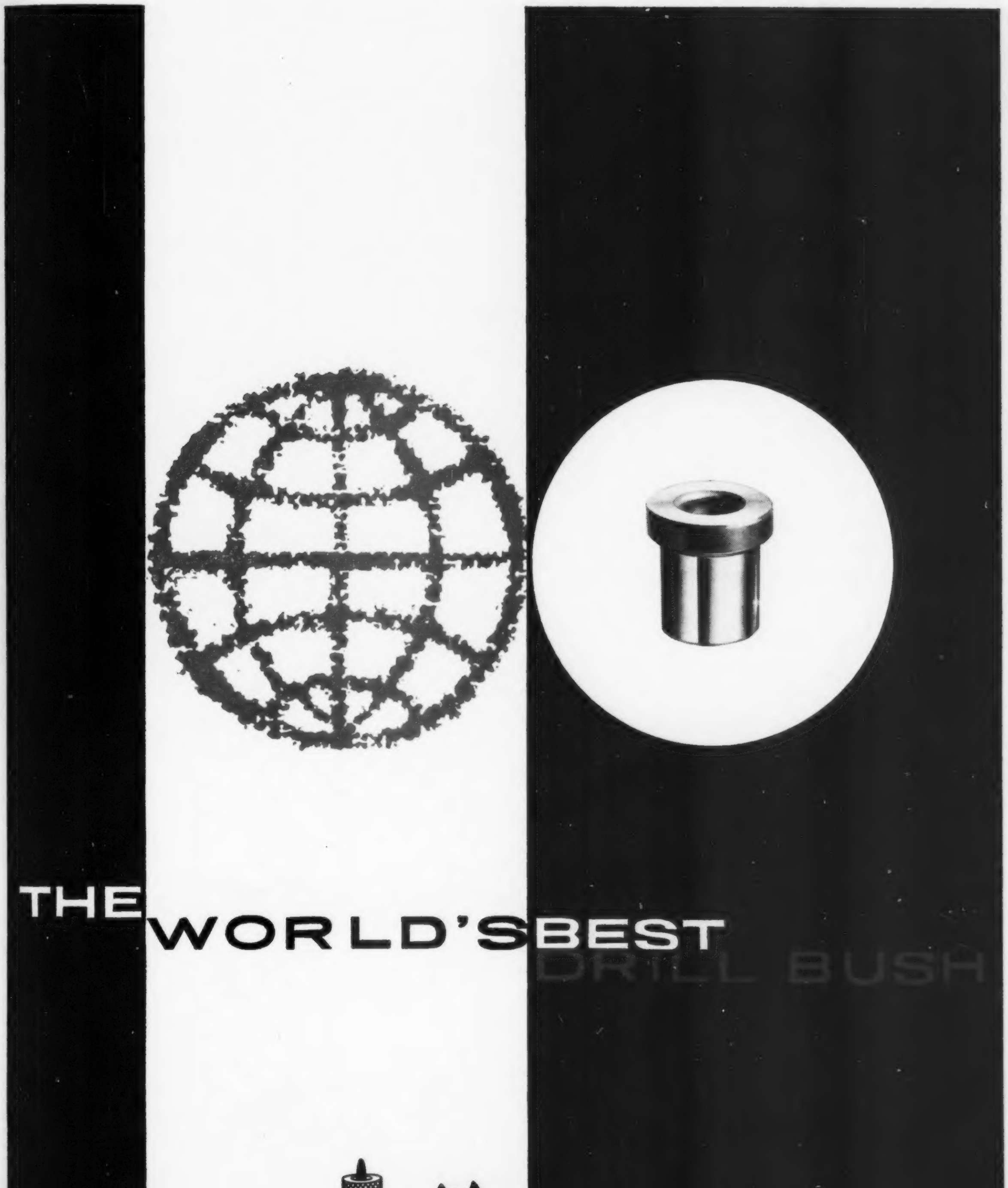
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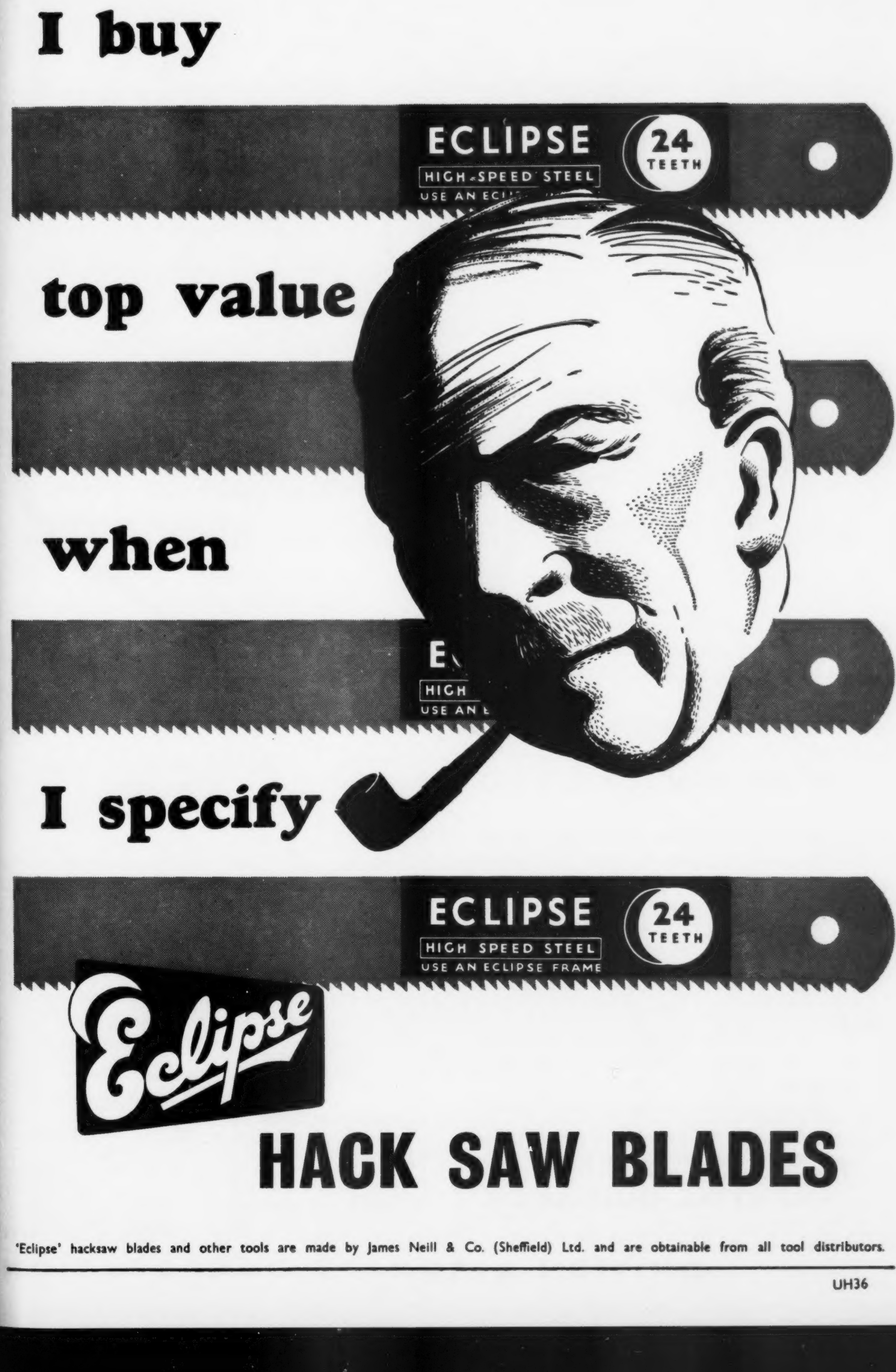
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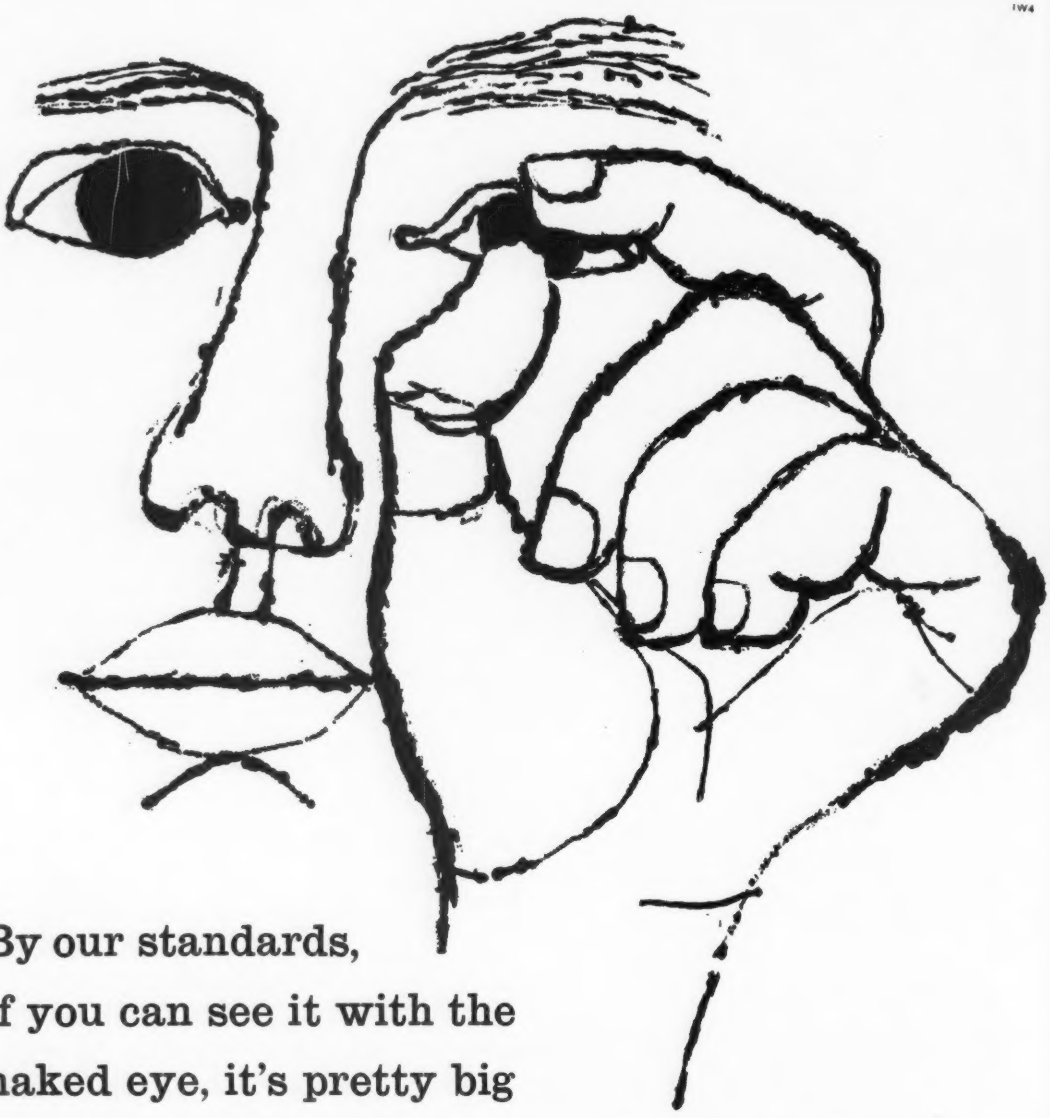

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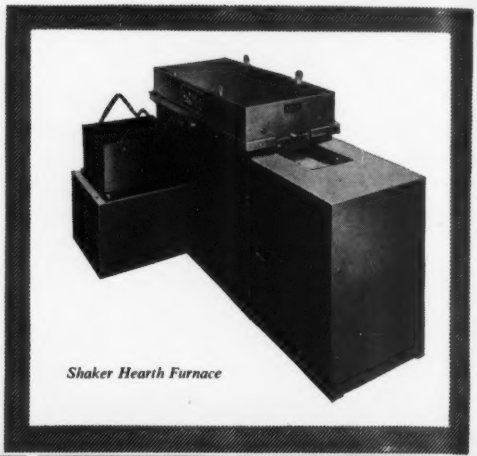

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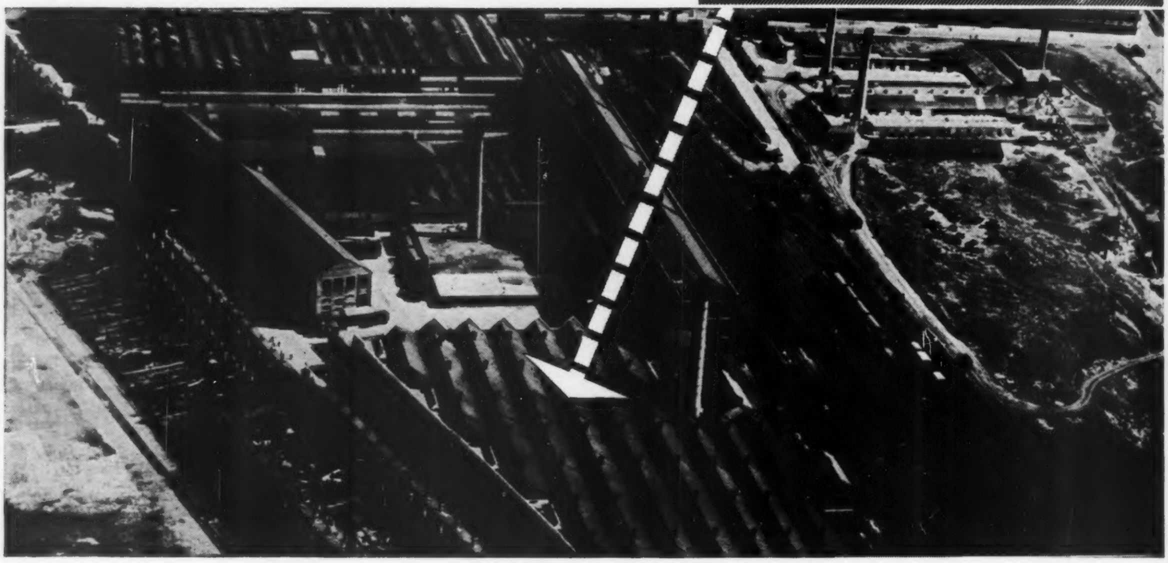

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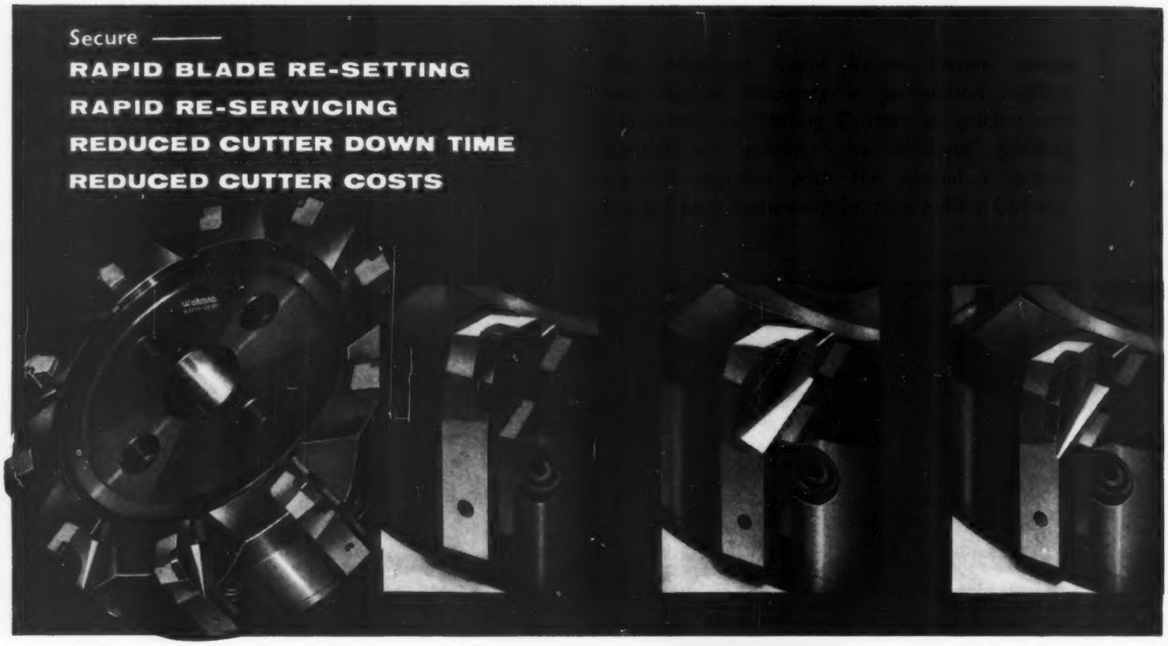

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The Production Engineer

THE JOURNAL OF THE INSTITUTION OF PRODUCTION ENGINEERS

VOL. 39 No. 12 DECEMBER, 1960

THE CULT OF THE SELF-MADE MAN

by JOHN MARSH

Director
The Industrial Welfare Society

A Paper presented to The Institution of Production Engineers in London, on 21st September last, as The 1960 E. W. Hancock Paper. The President of the Institution, Mr. G. Ronald Pryor, was in the Chair.

IT is a considerable honour to be asked to address your Institution. I say that as one who failed to become a qualified production engineer at a motor company, and in some ways my coming here will be a form of absolution for my errors in the past, in not gaining membership of your learned Institution! It is a special privilege to give this Paper because of its association with Mr. E. W. Hancock—and how pleasant it is to go to a lecture which is in honour of someone who is still alive. One feels like being gay instead of striking the solemn funeral note that may be necessary on other occasions.

This Paper is a tribute to Mr. Hancock, as a person, for the great work he has done for industry and for this Institution. I remember, as a senior apprentice, meeting him before the War, though he would not remember me; and since the War I have taken part in functions when he has presided with such distinction over this great Institution.

I also feel a little guilty, because long ago I gave up being an engineer and found an easier way of making my living, on the human side of industry.

In my present post I am sometimes called a representative of a hotbed of discretion. We believe very much in the human relations in industry. We would be most disappointed if all the human problems disappeared as a result of any lectures given under your aegis. I welcome very much the discipline involved in the preparation of this Paper. The Institution was good enough to ask me to choose a subject and I said, "I would like to give a Paper in praise of the self-made man". After a few weeks of thinking it over, I hastily altered the title because I thought that praise could be overdone. But the more I thought of it, following that, the more I preferred returning to the original title.

a tremendous impact

The discipline of looking into this subject made me feel that in the cause of human relations self-made men have a tremendous impact. When we count the distinguished engineers and *entrepreneurs* in our history, it can fairly be said that most were self-made men. A good number of our engineers have made unique contributions to the science of engineering by their inventions and latterly more through their sheer organising genius. This is particularly so in the case of The Institution of Production Engineers.

Most of these men started out in life with little academic opportunity, for the system denied them the privilege of a prolonged education; it was surely by sustained and sheer hard work, intuitive drive through sacrificial years, that they made their contributions to our industrial heritage. Self-made men have always made their mark in other walks of life too; this almost goes without saying, except that I must say it now for fear of being misunderstood later.

Today, I suppose we would agree, it is still possible to be a self-made man. One thinks of overnight financiers, trade union leaders and politicians. It is not possible to be a self-made man in medicine, in law, thank goodness, and, in a sense, in the civil service. I hope that it will always be possible, as a self-made man, to go into the civil service, and in war-time it had been proved that civilians, brought in, can have a revolutionary effect on that great machine.

In the Concise Oxford Dictionary the term self-made is applied to "a person who has risen by his own exertions—often with the implication of vulgarity, etc.". That is the unfortunate thing: with the class or caste pervasiveness which still haunts much of our society, this hint of vulgarity takes the edge off an otherwise simple and sober appraisal. I have known industrial men who, socially, have not been too happy that they have arrived as managers of factories: they have been much happier to be assistant master of the local foxhounds or Deputy-Lieutenant of the County. In our peculiar society, much of which one does not want to condemn, one may have success in industry or commerce on the one hand, and not necessarily acceptance in other places.

Nevertheless, I suppose all of us know what it means; most of us have known men of whom it could be said that they were almost entirely self-made, although I suspect that as the decades go by they will be increasingly difficult to encounter; furthermore, it will be an even more tricky task to single them out while they are young, thanks to the State-sponsored elimination processes—a kind of minor management selection—which start in the kindergarten—a prolonged nightmare for all conscientious parents.

The present system of educational elimination implants, I think, a feeling of self-inflicted failure into hundreds of thousands of boys and girls, and this does not augur very well for this nation's future. It should, of course, give just the right kind of spur to these young people, and make them aspire to be self-made—because they have been rejected elsewhere—but I think that in the affluent and cynical social climate of our time this result is very rare.

The self-made man is popularly supposed to "have come up the hard way", whatever that means. Surely most of us would agree that most success of an original kind is achieved by the hard way; venturing into the unknown is a tough experience whether one has an elementary education or a Ph.D. The self-made man in industry is now almost legendary and has a popular image which is something like this:

"He had a widowed mother from his early years; he left school at 14 (if he can say 11 or 12 it gives something of an extra *cachet* later); he ran errands, had several odd jobs under cruel masters, before he made up his mind that engineering or business was his line. He then endured privations and worked 18 hours a day, although joined when 20 years old by his pretty country girl wife. She bore him many children early and then proceeded to bore him as success came along." I always mistrust the man who says that he has never had a row with his wife. He is either a liar or suffers from amnesia.

"He built his business in spite of many near bankruptcies, but some friendly if exacting financiers came along just at the right time. Finally, however, he could not go wrong; he knocked out his rivals, made a killing by being alone in his field, and ended up as a wealthy, 'local boy makes good', phenomenon. In his declining years he enjoyed an envied reputation, with few friends but countless sycophantic admirers who claimed his acquaintance during the hard years with extraordinary stories of their influence for his good." We have all been told by old foremen of the way in which they helped—indeed, made—the most distinguished person in the factory, by being unselfish and giving the odd wrinkle and hint when opportunity occurred—and often there is a good deal of truth in it. "He probably never found social acceptance, and to the lonely end believed in his own unchanging opinions."

acquirement of status

Up till 1850 or thereabouts the engineer had no status at all. Educated people did not dirty their hands. The barber-surgeons were not accepted until they acquired some professional status by separating these two crafts or sciences. If one looks at the efforts on young people's hair these days, one is inclined to think of it as a science!

In his own way the self-made man has done magnificently; by courage, imagination and hard grind he burst through his contemporary scene and made

his mark. He often invented a new pattern of work organisation or business behaviour. I know three people who claim to have invented the term "ergonomics", for example. The self-made man could even found and endow a new branch of science. He was an original in his way, and usually a "character", too, and as such society would tolerate him, but somehow his children benefited more, because thanks to him they were lifted out of his social limitations.

This kind of image is certainly unfair to the particular case, but somehow self-made men have not until recently bothered about their own public relations. Even now, one suspects, public relations men (and women), those expensive boosters of individual or corporate ego, are hard put to it to reflect the whole truth about their benevolent clients.

assessment of virtues

If we try to assess the virtues in a self-made man most of us are bound to be somewhat introspective, for the urge to be original or different is in all of us.

A self-made man, i.e., he who has "arrived" in the eyes of his fellow men, is surely entitled to have something like the following written into the terms of an obituary notice:

1. His life of striving was created by circumstances, even though later he was wont to regard it as self-precipitated struggle.

When one looks back at anything one sees it in gentler perspective. In fact, one may have been forced into these things. If enough bulls charge at enough gates one of them will get through somehow. There were doubtless other people trying to burst through also.

2. He learnt most from sheer experience—by trial and error and not from books. . . .

I am always amazed at the truth of this, and the extent to which we do learn from our own and others' trial and error, although we use books to follow through and try to evaluate what we have heard from other people.

. . . When he received an honorary degree he was called "the happy pragmatist".

3. He was a student of human nature. By using colleagues and subordinates he prided himself that he could "sum up" a man in five minutes. He was intolerant of weaknesses in others, because of his strong belief in his own virtues.

I think one must say that men who have arrived at some time or other must feel that they have risen on the backs of others or even on the faces of others. I am not trying to exaggerate here: if we look at life realistically we appreciate that some people must go to the wall. It is a question of how you and they go to the wall today, in a gregarious society, that makes the difference.

4. He admired most those with similar qualities to himself. His most trusted lieutenants were on the surface men very much in his own image; if he drank, they were expected to; if he swore a lot, they would too. He felt more at ease with his own type.

I remember a works manager taking me to a social club one evening. He was surrounded by supervisors and foremen. No one else belonging to the works was there. He said, "I can't understand why nobody else comes". All the senior people of the works were there, and they were his faithful echoes. He was a very strong and dominant personality who retired, a little prematurely, a short time afterwards. It had nothing to do with my visit!

5. Of his other interests, if success came early and he had built a sturdy organisation to perpetuate it, he could spread his fancies and indulge in other interests. Otherwise his whole life would be bound up with his business success, his connections, his reading, his friends; all were involved in his self-made values.

Sir Richard Burton, diplomat, explorer and romantic, wrote:

> "Do what manhood bids thee do,
> From none but self expect applause.
> He noblest lives and noblest dies
> Who makes and keeps his self-made laws."

I think there is a great deal of truth in this. Most of us recognise that we would like to do that. Self-made laws are born of conviction.

Socially, the self-made man could be generous, extravagant perhaps; in artistic tastes he tended to be dilettante, and he felt ill-at-ease with those of a different cultural background.

Above all, history would judge him as having added to the sum total of human happiness, for he and thousands like him have, during the past century-and-a-half, hammered out the technological, economic and social revolutions which have peacefully convulsed these islands and the world beyond the sea.

a popular vogue

I would like to pass now to the time when the self-made man was much in popular vogue. He is not today, I believe. There is no doubt, however, that the apotheosis of the self-made man was reached in the second half of the 19th century. Samuel Smiles was the arch-priest of the movement to glorify and exalt the self-made man. In his best remembered book, *Self-help,* Samuel Smiles opens like this:

"'Heaven helps those who help themselves' is a well-tried maxim, embodying in a small compass the results of vast human experience.The spirit of self-help is the root of all genuine growth in the individual; and exhibited in the lives of many it constitutes the true source of national vigor and strength.

"Help from without is often enfeebling in its effects, but help from within invariably invigorates. Whatever is done for men or classes, to a certain extent takes away the stimulus and necessity of doing for themselves; and where men are subjected to over-guidance and over-government, the inevitable tendency is to render them comparatively helpless."

Samuel Smiles had something there, and the essence of what he says is important today. Are we not,

today, tending to be over-organised in much of life? In industry we, in a sense, gladly consent to it so long as we are paid to be over-organised—paid for our frustrations—because we know that the end product is needed in society; but there are areas of life where growing bureaucracy of various kinds, not only governmental, intrudes on whatever freedom we have. Smiles' comment is particularly true of the Welfare State—"overguidance enfeebles . . ." in that it enables one to "pass the buck".

His other contribution, writing about the lives and achievements of famous engineers and business men, is, alas, not sufficiently continued today. It is always a matter of surprise to me that few biographies of engineers and business men have been produced in recent years, and when they are they seem to be so unreadable. In many ways I believe industry, especially the big corporation, is queasy about this whole subject, and by not facing up to it one feels that the next generations of student engineers and business men are deprived of a real feeling of human continuity and tradition. I know at least three firms that have engaged journalists and others to write the history of the founder of the firm, only to find to their horror that it could not be published. But everyone knows that old Mr. So-and-So who started the firm was a man of frailty, anyway. Somehow I think we have to publish and be damned, in a sense, the lives of men who have made a contribution. Who is to say that industrial men alone should not have frailties? Perhaps the attitude is that not telling the student helps him, in his turn, to come up the hard way!

overtaken by events

I will only add that if Samuel Smiles were alive today he would be a national overlord for private enterprise, or would be as garrulous and dogmatic as an archbishop, with his pronunciamentos on human ills. So far I have discussed what might be called the historical self-made man. He was right for his time, but he has been overtaken by events. As in the world scene self-made Hitlers give appalling travesties of leadership in a gregarious world, so in industry we cannot any longer afford the ruthless, vain, self-made man with his dominant personal ambition, which is incompatible with our collective social conscience. I am not trying to put over any peculiar concepts of what social behaviour should be, but surely we have come to realise that whatever messes we are in, or hopes we may hold, we must work together in teams or by leadership, getting people to go with it.

The self-made man will come again and again, no doubt, but there are sanctions in law and in public opinion generally, which should curb his influences which are deleterious to our common welfare.

The fact is—and I cannot emphasise this too much —that today co-operation is needed between people internationally, within nations, in communities, in business and in families, and is the basis of any worthwhile philosophy. The alternative lies in such emotive words as exploitation, conflict, fear and war. If science and its application is to mean anything in the remaining years of this century, in terms of human values and happiness, we must take ethics more into account.

There are, of course, powerful forces working against co-operation. In the physical sciences man pursues exactness. " It either fits or it doesn't ", he says. Yet with human beings there is no such exactitude, and in several senses the engineer should know what tolerance means. In human relations—not to be called a science, I beg of you—we have a series of arts and skills in which perfection is impossible. Successive Presidents of the British Association in the last few years have all said that in the remaining years of this century, we must give as much attention to the human skills as we have done in the first years of the century to the physical sciences.

the key to success

For the able, potentially self-reliant young man the key to success tomorrow is through specialisation. In the church, in education itself, in the youth services and in all our complex and large organisations people must specialise. The learned bodies such as The Institution of Production Engineers are by their concepts irrevocably committed to this movement. One must say that the aims and ideals of varied professional bodies in the industrial field, when considered in juxtaposition, leave the layman bewildered if not a little anguished. New professions are emerging and older ones are expanding. Several times since the War we have seen a new hive-off of professional skills into new bodies. They seek not only to improve their status but to enforce standards of competence and conduct on their colleagues in different disciplines.

For professional reasons, if none other, they all need to encourage the social skills, of listening to the other man's view, of give and take and the arts of co-operation generally. At this stage I would just like to bring in two illustrations very quickly. I have mentioned that we need more of the arts of give and take. Serious studies of executive behaviour made in Edinburgh University and elsewhere nowadays indicate that in the dynamic company, with expanding markets, new ideas, processes and products, the senior people, technical and otherwise, are spending 80% of their day in round-table conference—one or two men chatting in the office or on the telephone—in fact they are engaging in human relations. Even in the factory on constant production, 43% of the time is taken up in this. The more senior one becomes, the less one uses professional knowledge of science and embraces other skills to which one is not necessarily suited and which apparently we must learn the hard way.

My second illustration concerns the company chairman who wanted to appoint eight men from within the Company to the main board. (It is a true story.) They were men in their forties and fifties. Five were within a year to become chairmen of subsidiary companies. He took them off to a hotel for the weekend and said, "This is a departure for the company. I am taking a risk. You are high in your professions.

You are paid well and have had good results so far. Will you try and be honest with each other and with me this week-end and tell me what are the weaknesses in yourselves at this time of life?"

After their discussion they said, "We have five areas in which we are not happy. First, we are one-track minded. We have only, so far, taken our own special knowledge seriously, never really giving due credit to the other branches of the business. If we are going on the board we must do that. Secondly, we have no knowedge of economics." This is, perhaps, a national disease. I have never met anyone, even someone knighted, who really understood how the bank rate went up and down!

"We are socially ill at ease. Some of us have never given time to the social graces necessary to represent this company and do business with people. How do you make conversation with a University don; what small talk interests him?" I would like to know the answer myself sometimes. They also meant that they were socially ill at ease with the spirit of the time: that they were not sure that they knew the various influences at large in society.

"We have no personal philosophy. We do not know what to believe—whether we should have any personal faith, or whether we have any philosophy for ourselves or of industry itself.

"What about the wife? She has been the victim of our circumstances for years, and now we are going on the board and will become chairmen too. Do you want her to gear her whole life to what we have to do, to be party to what is in a sense a sort of total mission in life?"

I believe these problems exist in many executives as a result of over-zealous application of special knowledge. In this regard, however, one must give due credit to the modern schemes of management training in industry, or executive development as it is better called.

In the conflicts of professional know-how, the bodies of which I have spoken invariably have resort to the amateur to decide—as do Government departments when they are bogged down with too many facts and no sense of direction!

problem of conflicting needs

In promoting standards, research and the free exchange of technical knowledge, professional institutions render an invaluable service to industry, and yet I would submit that a very real problem lies today in the conflicting needs of increased specialisation and the general culture. There is surely an imminent danger that we are concentrating on producing a technically skilled nation by mass production methods as opposed to a truly educated one. We must proceed with technological progress but we have yet to recognise the parallel importance of the liberal arts, social skills, and what I would like to call the wakefulness of man's spirit.

Could I suggest that one day your Institution may give a lead, because of your great experience and widespread influence in this country, in advocating a federal get-together every five years of organisations like your own with organisations dealing in social skills, not to federate but to have a look at the way in which all this is going; but do it in a multilateral fashion, not unilaterally, for such discussions take years to complete. Would it not be possible at the beginning of each decade to plan a week's get-together for the serious purpose of seeing whether we could not get some reconciliation of the kind to which I have been referring?

the "organisation man" cult

Across the Atlantic the cult of "organisation man" has arrived; there are depressing signs that it has begun to arrive here too. If it has I would blame the Universities, particularly the older ones, for their curiously negative—almost hostile—attitudes to the development of an industrial society. Whether this is due to intellectual snobbishness or mere laziness for over a century in recognising industry's part in our national fulfilment, it is difficult to know. The fact remains that whilst accepting industry as a necessary evil, Universities consistently appeal for its money and at the same time tend to regard the graduate who enters it as a lost soul who, in selling his talent, has also sold his discretion.

This is, I think, still true of some of the colleges of the older Universities in particular. The graduate is badly needed in industry. He is wooed every Sunday in tombstone advertisements which invite him to apply for all the wonders of this world. When he is about 35 he has an immense advantage over his contemporary who has had to come up the hard way. The discipline of University training enables him to cut through to first principles far more effectively than the other man, for a while at least.

the place of apprenticeship

Here may I just put in a plea—not that one should use your platform for pleas—that perhaps we should look again at the cause of apprenticeship. Its numbers are still declining. I am in touch with a good many schemes and one of the reasons why it is not getting the attention it should is that the full-time officials such as apprenticeship supervisors, education and training officers, who 10 years ago were dealing with the subject, have today been promoted to dealing with the vast subject of management education and training; so there is no one coming on to keep up the standards of apprenticeship.

Apprenticeship of various kinds has a major part to play in years to come. One meets one's contemporary apprentices who have done extraordinarily well in industry. Twenty years ago they would not have exchanged that beginning for a University training, but today the overwhelming weight of organisation, money and everything else is for the University, to the extent almost that parents and industry have concentrated on filling the science places and it is comparatively easy to get an arts place. Is this not something to look at if you have a federal meeting

in the next few years—apprenticeship and the relationship of this system to graduate training?

a new philosophy of education

Industry and the exigencies of technological and consequently social development have now forced the educational system to recognise the need for a new philosophy of education; it is good to know that experiments are afoot which will lead to such schemes which were described in *The Times* recently as aiming "to break down the packed specialisation of grammar and University education of the present time, and put something civilising in its place". One means here such things as the Trevelyan Scholarships, the Cambridge experiment with the Engineering School to bring in a one year course of Tripos standard in certain liberal subjects—four years of graduate training and one year of liberal training. I am reminded of a firm in Chicago which puts its foremen through a course of "Plato, Socrates and Galbraith" at the hands of a professor who flies in from San Francisco every week. The Arts graduate may yet come into his own. I know of two or three large companies that are coming round to the view that the difficulty of reconciling the specialists is so great that it is perhaps the Arts man ultimately who, with his breadth and judgment and wisdom can, given experience, provide the answer. It is worth thinking about that if we cannot come to grips with this problem industry may have to act arbitrarily, as it always has to in the end.

The early specialisation of which I have spoken has also been aptly called "the pressure cooking in education". But to return to "organisation men": those of us who have visited the United States will know that with its polyglot of peoples, that industrial nation has its own mixture of cultures and social customs. In the vital exchange of technological know-how with our American counterparts we do not necessarily have to embrace their way of life—or they ours. Yet in our impatience and in our general failure to give thought to what I would term our indigenous social strategy, we at present copy much of North America's affluent society and its accompanying human values willy-nilly, the sound with the sick.

The "organisation man" of the United States is one who has to fill a carefully designed and carved niche in the bureaucracy of Government, industry or commerce. He is trained and expected to be successful, when all is well with national or local prestige and economy. However, and I cannot emphasise this too strongly, I believe that in the phases of failure or uncertainty, the organisation man is very much at a loss. America's own failure to lead internationally in recent years is surely due to the fact that she has been accustomed only to success. It has been a continued success story. In 1898 they overtook us and ever since they have gone up and up, with occasional crashes from which they have recovered quickly. They have been forced into world leadership by great industrial capacity. I believe that they are not accustomed to it and wanted only to deal with the positive success that they had had for so long.

The "organisation man's" well-oiled systems, predigested aims and motives, group pressures and what not are designed and applied to bolster the general American feeling of insecurity in a nation new to power, and whose roots are not deep. When he comes across "untogetherness", if I may pervert our language still further, he lacks courage for the empiricism which is at the heart of any free society.

I visited a magnificent factory in New York State. At the end of a day I said to the manager, "I have never seen a more exciting kind of factory, or better organised. You all seem very happy". "Yes", he said, "and we are worried about it. We are going to have a psychiatrist in to find out why we are so happy". We would not think of doing such a thing, but they somehow need to be reassured!

A similar problem is presented by a feeling that they must analyse the reactions of their executives, and the causes of failure and success. I agree that some research is necessary, but one does not have to take the results of such research with deadly seriousness. Have any of you ever been to an American management conference? Have you ever come across such a solid "wodge" of seriousness? There is precious little humour or humanity in such a conference! We must not copy their polyglot pattern, or the way that it affects them. We have our own way of looking at these problems. It is in considering this kind of situation that some of us will respect Samuel Smiles and his sublime confidence. The organisation man is quite the opposite.

the present day ideal

I have so far tried to portray the two extremes of the self-made man and the organisation man. Now I would like to make a case for the ideal self-made man in the present-day scene.

The ideal self-made man must be an educated man in the widest sense; amassing information and acquiring technical know-how are obviously insufficient. I often feel that the mere mugging for degrees and diplomas lulls many a youngster into a desperate trap of false security, which causes a lifetime of regret if he fails to learn how to use knowledge. The ideal self-made man must be a self-reliant individual, with a creative imagination, nous, and the capacity for logical thought. He must from time to time indulge in curious thoughts, to shape questions, to seek and sell answers, to design new experiences for himself and others, and notice what happens as the result of such ventures. He may, of course, incorporate several specialisations in his career—it is being done in this country quite naturally—but if he wishes to make a major contribution, I hope that in some areas of life he will remain an ungifted amateur. If given most of this he will be tolerant; but the great gift I think to be a sense of humour. In our accumulation of industrial gimmicks, gadgets, -ologies and -isms we tend to be over-serious about ourselves though not to the same extent as the Americans; to have a good laugh (or cry) at our follies provides a much-needed catharsis in the alchemy of the happy self-made man.

This self-made man is necessary to our industrial future, which promises to be no easier during the re-

maining 40 years of this century. Given peace in the world, the great industrial problem should not be that of production but in the distribution of the fruits of production, with inequities of wealth and explosive population growth, nationalism and race relations, the balance of work and leisure, and the building of just societies. Many of the problems ahead of us are not technical but social. There is much for us all to do—for this is the perspective and we must if we are to lead know where we are leading to.

Tomorrow's self-made man has several clear pathways in front of him; he must realise:

Firstly—that he needs ever more and wider basic education.

Secondly—that before he earns his living he will be well past the age of manhood and his social adjustment requires patience.

On our Youth Services Committee we were much impressed by evidence that the younger generation is maturing 18 months earlier than it did 35 years ago. I am told that this helps to account for the shortage of choir boys in certain parishes!

Thirdly—that his education does not end at 21 or 25. These ages may mark the end of the beginning; we have learnt in late years that the successful industrial engineer or executive (or he may be both) never stops educating and training himself. If he gets to the stage where he knows it all he is in reality giving up a major struggle of life: if, on the other hand, he increasingly realises that he knows less, then he may be reassured that he is on the right lines.

Fourthly—that a man generally has three incentives to work:

(*a*) to maintain a reasonable standard of living—even though in modern society with inflation, taxation and vexation, if he is honest he is left with little more than hope!
(*b*) to achieve status in a profession or trade in his workplace and the community—not to mention in the eyes of his wife!
(*c*) to find an intrinsic satisfaction in all that he does.

I believe that the engineer and the executive are among the elite of people today who can enjoy their jobs if they wish. There is variety, not necessarily of their own choosing. They are caught up in a changing situation, and one can find an intrinsic satisfaction in change, if one is so minded.

Finally—that it is the whole man that counts. He needs to weigh up in his personal balance sheet the complementary facets in his life—those of belief, homage, family life, work, citizenship, leisure and maybe just idleness. In all this he must ask himself from time to time: "Where am I going? What do I want to give to life as well as get from it?" These are all philosophical questions.

The tantalising thing about all this is that in one sense we never arrive anyway. When is one able to say: "I am self-made?". So far? What next? I have always believed that self-reliance is continual striving—steps towards self-fulfilment. In a very real sense life is a series of ephemeral fulfilments; it is, however, in the restlessness of man's spirit, his ideals and his emotions that we need to be in awe and feel inadequate. I am strangely unhappy with those who are dogmatic in these matters. There are many frontiers in an individual human being over which another person must not stray or dabble unless by invitation—and even then only on a basis of mutual trust and love. Here the marriage relationship is cautionary to us all.

I was most moved a few weeks ago when a distinguished man, who had been married 50 years, said to me, "At night when I lay my head on my pillow and my wife is on the other, do I know a bit of what is in her head?" Even with the marriage relationship we really do not get to know each other beyond a certain point. And here is where organisation man is wrong. If anyone wants to alter the personality of the individual to suit the business he must find out whether that individual really wishes it.

The cult of the self-made man has something to commend it, in the setting of a social age and if we have taken notice of history. Oliver Wendell Holmes—who could always puncture pomposity—once said: "Everybody likes and respects self-made men; it is a great deal better to be made in that way, than not to be made at all!"

self-judgment

In conclusion, I would return to what the ideal self-made man should say in self-judgment about his work when surrounded by his friends and his peers:

"I have tried my best from youth to old age;

I profited from my teachers and taught freely in my prophecies;

I did more than I was ever paid for and tried to improve my profession by example;

I took pains in my work to find out what 'they' expected from me and got on with the job;

I kept my subordinates in the picture and left them alone to get on with their tasks;

I was privileged to discover one or two young men far better potentially than I ever was, and I gave them their chance: they rewarded me by what they chose to call their discipleship of my example;

when I retired my work did not die but entered into a new and better phase;

and my success, what is it? Not only in the goods and services I have helped to produce or render, or the profits that teamwork made. The real reward has been in the extent to which I have been able to be an influence for the good of my fellow men;

and long ago I learned that God made man."

I said earlier that the ideal self-made man is necessary to our industrial future. By this one means that no matter how complex our educational system, our industrial organisation and our social direction, we need people who will be non-conformist at certain times; they will be unpopular, their ideas may well be inchoate over long years; but out of their loneliness in the envy and isolation of their fellows, they will produce something to add to our national character and the everchanging tempo and gregarious temper of our day. Such men (and women) need not achieve greatness (though some will) but in the corners of our offices, factories, shops and in fact wherever people work, these few will be the custodians of our national progress and well-being.

For they will continue the historical human tradition that Britain adds much to the conduct of society everywhere.

DISCUSSION

Dr. G. S. Brosan (*Further Education Officer, County Council of Middlesex Education Committee*), opening the discussion, said that while he must congratulate Mr. Marsh on the excellent case he had presented, he reluctantly needed to quarrel with Mr. Marsh's interpretation of the way in which the self-made man came into being, and his claim that the self-made man forced himself on to society. The quarrel was with the suggestion that the drive of the self-made man was due to circumstances: surely the drive came from within the man himself. There were all types of people, as many psychologists would attest. One could classify them into people who saw similarities and people who saw differences; into people who thought for so long that they never acted and people who acted so fast that they never thought. But these were not significant differences in the present context. The main point was that some people had "fire in the belly" and others had not.

His disagreement with Mr. Marsh would have been much greater had he not said what he did at the end of his Paper . . . "We must have men like this . . ." Of course one must. He would refute the suggestion that the Americans had accepted the "organisation man". They had not. A great deal of questioning was going on, and he would just like to read from the book "The Organisation Man",* a passage on trainees in management:

"From company to company, trainees express the same impatience. All the great ideas, they explain, have already been discovered and not only in physics and chemistry but in practical fields like engineering. The basic creative work is done, so the man you need —for every kind of job—is a practical, team-player who will do a good shirt-sleeves job. 'I would sacrifice brilliance', the trainee said, 'for human understanding every time'.

"And they do, too."

"The author takes this passage and proceeds to tear it to bits", Dr. Brosan said. No one in the United States or anywhere else who had read that would be convinced that the organisation man was the one for their society. The book even included a chapter on how to cheat in personality tests.

If one had the drive of which he had spoken what did one do? The engineer found out pretty quickly that he could get more money and more social credit by not being an engineer; so he started to work his way up the administrative ladder. He could not do what people did a few decades earlier, finding obvious things that had not been invented and making his pile. To that extent the engineer had advanced. The high financial rewards came not to creative engineers but to creative controllers and commercially-competent exploiters. The engineer dealt in, and trusted, facts. The commercially-competent exploiter, or the psychological administrator, dealt in or led people. Was it easier to deal with a fact or a person? Perhaps it was not quite as wrong as it might seem for the administrator to get a little more money. The trouble was that he got a little too much, but one need not go into that.

Could he have two tilts, continued Dr. Brosan, at no one in particular? First, it was easier to train a manager than to train an engineer. It did not matter when one was studying economics and came to the theory of banking whether one knew very much about the manor system; but he would defy anyone to do calculus without being first able to do long division. Engineer training must be consecutive. That of the manager could be done in bits. Also, management training was so concerned with facts that it was always downward looking instead of forward looking. He wondered whether that had something to do with the subject under discussion.

Second, if one could get a self-made man up on the platform, would he say, "If you are all so clever, why aren't you all rich?" It might not be in the best of taste but it would underline the fact that we had not all got the necessary drive, which, he felt, came from within the man himself, and would make itself felt whatever his walk of life.

What did Mr. Marsh really want out of education? He had first said that success came through specialisation, and later that we must not specialise in the sixth

* Jonathan Cope, London, 1957.

form. There must be some sort of balance. Where did one begin specialising, and how much should one specialise? Did he really mean that Universities should be the handmaidens of industry? Surely this was the last thing to seek if we wanted men who could think for themselves and for industry. The technical colleges were more closely bound with industry, perhaps too closely. The people one trained must be made to think, perhaps trained to think. He would like to know how this could best be done: it would not be easy, however.

Mr. Marsh replied that he had singled out the older Universities as having rather missed the way. The discipline of thinking was the main thing to be taught, but it must to some extent be related to the circumstances of the day. It was unfortunate that the products of Universities were often teachers and that these were frequently cynical about industry and commerce. A lot of this was unhealthy.

He had thought not of Universities being the handmaidens of industry, but in some form of partnership with it—the kind of thing envisaged by Professor Baker at the Engineering School at Cambridge.

The older Universities had not, in the last fifty years, made a major contribution to the social consequences of industrialisation. In the social consequences was involved the sum total of human happiness. In this respect they had behaved in isolation. One found that graduates, the contemporaries of one's children, lived in a different world and often thought in the light of circumstances that were common a century ago. A genuine mutual respect between industry and the Universities was often lacking, and the country was losing thereby.

Education should, of course, be directed to teaching one to think and to probe a little into the nature and destiny of man. This might sound pompous, but it was not necessarily intended to make one a better works manager so much as to help one to live.

Mr. D. L. Nicolson (*Managing Director, Production Engineering, Ltd.*) felt that the author had been a little hard on the organisation man. He did not know whether he himself was aspiring to be a self-made organisation man or not, but anyone who studied organisation was forced to the conclusion that people were so much more important than any system. It meant that if the individual, whether production engineer, cost accountant or whatever, was properly trained in his function, which included understanding the functions of his colleagues, the organisation would work—rather than by the application of any particular system. That was fundamental, and well understood even by the "organisation man".

Today there was greater opportunity for higher education through State aid. Only about 7% of school leavers were potential leaders and a large proportion of this key material might be those who went on to higher education instead of entering industry through apprenticeship. These greater opportunities were themselves, of course, admirable, and in a way men were self-made men if they won a scholarship. The difficulty was to attract them back after higher education to the shop floor or to a career in production. In fact they might start with quite an inferiority complex compared with the young practical man who had been in the works since leaving school.

One of the things that could be done in a work study department was to bring together the professional rate-fixer and methods engineer, the young graduate learning the economic facts of manufacture, the shop steward who was taking an appreciation course, and the future foreman who was perhaps being trained by a process of circulation. These were the sort of "human" engineering problems that had to be tackled today. He would like Mr. Marsh's opinion on whether the 7% of potential leaders were indeed largely the ones who were being led away to higher education by the State education system.

He also wondered whether enough was done to provide incentives for the man on the shop floor who did not have the opportunity to serve an apprenticeship and become skilled. In some other countries, including America, it was possible for a man to acquire skilled status at any age or stage in his career. In the Merchant Navy there was an admirable ticket system whereby a young engineer could obtain the qualification for chief engineer whether there was a vacancy or not. He had often wondered whether in industry there could not be an inspector's, charge hand's, planning engineer's, or even a works manager's ticket, along the same lines. But should the organisation man devote time to providing such incentive systems? Or was it more logical to say that if a man had "fire in his belly" he would find a way of getting up there himself? He had enjoyed the Paper very much indeed.

Mr. Marsh said that in the last ten years industry had given the impression of ceasing to be preoccupied with shop floor reactions; for example, joint consultation had failed. There was much evidence that industry now sought an elite of top managers, engineers, etc., and was paying great attention to finding the 7% who were to lead. Unless it thought out the implications of this Britain, as an industrial nation, might encounter real difficulty, for the man on the shop floor would feel that without early preselection there was little chance of success. Ten or eleven years ago one would have found at a works managers' conference that more than half those present had come up the hard way. In another ten years there would probably be very few who had been able to force their way into the elite in this fashion.

The concentration on the elite was necessary in every civilisation—whether in a dictatorship or a democracy. Nevertheless one should not let this preoccupation blind one to the frustrations on the shop floor. It had been said recently that we would have to pay more to people for their frustrations, the chances they had missed, the threat of redundancy and so on. People tended to be paid for being less resistant rather than for what they did.

The chances to rise from the shop floor had become fewer, partly because of a changed educational

system. Gilbert Murray had once been asked when he had really felt he was growing old and had said, "When resignation took the place of hope". Resignation that one had nothing to look forward to but the pay packet could lead to action of various kinds, possibly political. The unions in the United States had got so far with their industrial demands that they were now tending to achieve a greater status in society.

On the question of the 7% who would become leaders, Vice-Chancellors of Universities would tell one that in recent years the average student had not felt it necessary to bother about anything but getting his degree, going into his first job and getting as much money as he could before he was 25. The man who came up from the shop floor had a genuine knowledge of atmosphere and the way in which people reacted that could not be obtained otherwise. From the point of view of human relationships, was it wise to exclude from leadership men coming up in this way? We might yet have management, technologists and some union leaders who had never known at first hand the atmosphere of the shop. This lack in leadership could have a serious effect on morale in industry.

Mr. G. A. J. Witton (*Member of Council*) said that the first impression he gained on seeing the title of the Paper presented by Mr. Marsh was that they were again embarking on the process of debunking the self-made man. This had been the favourite pastime of society and dons over the last century.

Mr. Marsh in his Paper had, however, been more constructive. He had certainly debunked the self-made man, past and present, but he had also provided the specification for the self-made man of the future. Mr. Witton could not fault this specification, and could only wonder how it would be achieved.

He also detected a suggestion that Mr. Marsh might well support the view that business was best run by amateurs. He did not agree that the qualification for taking a broad view was a complete lack of knowledge of the subject.

It was fortunate that the future requirements of British industry were not dictated entirely on the basis of what was happening in the very large companies, for the major part of our industry was made up of very small companies employing less than 500 people.

It must be accepted that in the future there would be a growing tendency for small units to amalgamate because of the increasing cost of scientific and technical development. Of the present it could be said that almost all of our small businesses were run today by self-made men who started life as craftsmen, and many had, by their own efforts, expanded to a remarkable degree in the past decade.

Mr. Witton felt that there was still a need for the self-made man, and large industrial groups in both the United States and in the United Kingdom were making a real attempt to create the opportunity of retaining the atmosphere in which he flourished, by dividing the large group into small units for managerial purposes.

In the United States the Board of Directors no longer interfered with the operation. The President and the Vice-President ran the business and the Board of Directors met only on rare occasions to exercise financial control, hire or fire the Presidents and protect the shareholders' interests. Today, in Britain, there was a growing tendency for the Boards of operating companies to be constituted of self-made men who acted as functional Directors, and in this way they operated in a very similar manner to the Presidents and Vice-Presidents of American companies.

The problem of the future, as Mr. Witton saw it, was to provide men with sufficient breadth of vision with a system of training which provided for a high degree of academic training and insufficient opportunity for acquiring practical experience.

In the company with which he was associated they had well-organised schemes which, with the help of local education establishments, were designed to provide them with many craftsmen and technicians. But with few exceptions their existing executives were self-made men, and the problem was to find the next generation of executives. A recent review suggested that those most likely to qualify in the immediate future were the men from the floor of the shop, who had come up the hard way.

They would like to feel, concluded Mr. Witton, that some of their graduates would achieve managerial level, but results to date were disappointing. He would be grateful if Mr. Marsh would express his views on this matter, as he felt that the future of British industry depended largely on the quality of the executives it could provide.

Mr. Marsh said that he had been referring to the shortage of trainers, not of apprentices. Some firms that two years ago had only one boy applying now had 150. Technical and practical training had to be balanced by training for life. He had just come back from Oxford where 450 of the best apprentices in Britain were attending conferences held every year for eleven years. To any company that sent them, he would say that the overall impression was that these lads were on a kind of technical conveyor belt because of their cramming plus practical experience, the latter not being as well-organised as it might be. Also, there was a need for something else, perhaps a regular discussion once a month for an hour or two with the supervisor or a manager about matters in the department, about how the job was done and the company was organised.

Most were anxious to marry early, and were surprisingly interested in household economy and the way in which to get money to put down on a home. He did not advocate that those present should become marriage guidance counsellors, however well fitted they might be, but that they should help, where possible, in the development of discussion and the discipline of thinking.

Most apprentices felt that the unions had thrown them aside. He was inclined to agree. Few unions had a youth policy, even less a full-time youth officer.

These days young people, with the help of their parents, were extremely well informed—mainly because of the advent of television—and should be encouraged to be articulate about adult values. Social development of this kind would repay an organisation handsomely. Apprentices should be encouraged to form their own apprenticeship association. He was sure that anything that one could do for learnership was fruitful.

A course in how the company worked, given three months after joining, and lasting perhaps a week, would make an amazing difference to the frustrations of young people, whose whole attitude was moulded during the first six months, and who often began their life with a firm wondering where they stood or what was expected of them. This was vital to relationships later on. It was a subject in which he believed passionately.

When he had discussed, in the United States, a problem similar to that of Mr. Witton they had said, "Perhaps we want planned empiricism". This would produce a kind of super-organisation man with a bit of pragmatism thrown in. The organisation had to allow for this but not go too far in 'making' a man.

Dr. J. S. Tait (*Principal, Northampton College of Advanced Technology, London*) said that Mr. Marsh had begun by saying that most distinguished engineers were self-made and had come up the hard way. This was true largely because formal technical education had only begun about fifty years ago, and in speaking about those who were successful one omitted to mention those who had perished by the way.

When one spoke about the self-made man of tomorrow, one had to realise that he might be successful and no less eminent than his forebears, but he would be much less "self-made". It was likely that his talents would have been noticed at an early age. He would have been selected for a sound fundamental technical education coupled with appropriate practical training in industry. From his observation of the work around him he would derive inspiration and he would be subjected to many of the influences of radio and television. By his reliance on books and all those outside influences he would much less deserve to be called self-made.

Mr. Marsh had given priority to a wider basic education, and Dr. Tait had heard Dr. B. V. Bowden, at Manchester College of Technology, say that the qualities displayed by the most distinguished engineers were those possessed by small children—curiosity, zest for life, initiative and enthusiasm: that somewhere on the way through school these qualities were atrophied or destroyed. Children were required to conform to a pattern. By the time they were 13, all initiative having been knocked out of them, they were asked to choose from an arts or a science course and to fit into this elementary pattern.

But leaders did not conform to a pattern and this had to be recognised even in school circles. It was hoped that one effect of the Crowther Report would be to broaden the school curriculum so that children were not simply soaking up information in narrow and specialised fields without thought of personal attitudes and behaviours.

Mr. Marsh's second point was that before the self-made man of the future earned his living he would be well past the age of manhood. If this continued to be true, it would be a serious mistake. In the discussion it had been said that the University man was often deficient in certain personal qualities and perhaps this could be remedied if he had an interval between school and University when he went into the world to earn his living. This usually resulted in a rapid development of his personal qualities and character, and if he could be financially independent, it contributed to his manliness and responsibility of outlook.

This was one of the valuable features of the Diploma in Technology schemes. The boy who left school with University entrance qualifications was required to spend six months in industry and in college alternately over a period of at least four years, and the wages paid by industry were such that the majority of these young men were financially independent of their parents and earning their own livings by the time they were 21 years old. The importance of this financial independence could not be overstressed. Mr. Witton had spoken disparagingly about some sandwich course products, but it was too early to criticise the Diploma in Technology students. Dr. Tait said that in his own College there were about 800 students in these courses; more than half had three Advanced Level passes while the University specified two passes at Advanced Level for entry. They had all been carefully selected and many were quite outstanding in academic promise and personal potential.

He would agree that education must not end at 21, but it was a little unfair to expect a man to educate himself in his spare time. By the time he was 25 he had family responsibilities, and industry must find some way of releasing him for substantial periods so that he could go back into education and equip himself with the mathematical and other tools with which front-line research problems were attacked. If we were to compete with the Continental system, post-graduate courses of study for selected students must be developed urgently.

One disturbing feature about the technical education system at the moment was that until a man was about 25 he was taught how to apply science to eliminate the use of man. Automatic control systems gave the idea of man becoming redundant but by the age of 35 years, he found that an increasing proportion of his time was devoted to human problems. All along the line opportunity must be found to liberalise his education and to prepare him for a fuller understanding of human relationships which were essential to his full development.

Mr. Marsh said that he was so full of admiration for what was being done at the Northampton College of Advanced Technology that he could not add much to what Dr. Tait had said. He would like to bring in a concept of the educational process: that an educated man should, first, be in a state of growth

all the time. If he were not something began to die inside him. It could be growth of different kinds—perhaps a new experience or job. Secondly, his skills had to keep on being furbished and refurbished. He would probably also acquire new skills. Thirdly, one could not do this without from time to time having a sense of fulfilment. Fourthly, no man was educated until he knew the meaning of loyalty. These things could be had at work, in the home or in the community. If one could not grow at work, one could become a better family man or citizen and so on.

Some of the happiest people he knew were those who decided they were not destined for the front-line and decided to put their home life first rather than work for a little more money or power. This was not cowardice but self-realisation. The foreman who said, "I can go no further and will be content", was much wiser than the executive who had little promise of advancement and would not recognise it. He was happier because he had a sense of fulfilment.

Mr. E. C. Gordon England (*Consultant*) said that he had enjoyed Mr. Marsh's Paper, but even more the challenge to the Institution contained in his formula for the future self-made man. He would like the Institution to tackle it as a problem to be solved. Some of Mr. Marsh's wittiest thrusts should be taken very seriously. In industry one could find self-made men who would fit admirably within Mr. Marsh's specification. Ought not the Institution to encourage the wider production of such men?

He happened to be interested, in a directive capacity, in an adult educational establishment and in that connection he found a great distrust in "virtues" of the self-made man. This was not surprising, for if one looked at the popular image of self-made man as represented *in excelsis*—in Parliament!—one had reason to wonder whether this kind of self-made man was a really good thing after all. The adult educational establishment with which Mr. Gordon England was connected worked for two other separate bodies actively concerned with adult education. One was in respect of the preparation of ordinands for the Church—in this case it was trying to give them an idea, outside of their special vocational training, of how they could fit into commercial and industrial life; trying to build into them some concept of what constituted the whole man. They were finding this experiment extremely helpful and useful.

The other organisation, "Overseas Service", was concerned with, and had been with great success for some time, the training of people, when they left the United Kingdom, to fit into their jobs abroad in a social sense. In these "Overseas Service" courses the wives were brought in too, so that they might also fit into the new social conditions which their husbands and they were about to experience. But this was not done for people remaining in this country!

Mr. Gordon England suggested that if something similar could be done in the United Kingdom, half the trouble experienced with rising executives and their wives could be overcome. Might not the evergreen and vigorously advancing Institution help to foster such training in this country?

Mr. Marsh questioned the advisability of industry interviewing wives and husbands together when a move was contemplated, however much one might recognise the great upheaval sometimes caused by uplifting a man and his wife and placing them in a different social or cultural climate. The wife might be helped to go ahead and inspect houses, etc., but it would be rather up to the husband to take the responsibility. He must not be able to say, "The company said that you have to do it".

Mr. F. A. Oakley (*Member*) said that many members of the Institution did their best throughout their lives to carry out what Mr. Marsh had been describing. There was nothing really new in this world. The greatest thing one could aim at was the building of character in the home. In the self-made men of his youth, character and loyalty played an important part. He had been impressed by the work of industrial chaplains in the breaking down of frustrations.

Everyone could not be a manager but men individually were important, and love and understanding could achieve a great deal. Given this, the self-made men would continue to come along, but no one would succeed without a creative desire to give of his best to others.

Mr. A. P. Oppenheimer (*Member*) said that the description of the self-made man which they had been given would not prompt one to think in terms of teamwork. Mr. Marsh had rightly said that the key to success tomorrow was specialisation, and with the number of specialists together in a modern organisation, the need for teamwork was more real than ever. The job of the self-made man was to work as the leader of such a team, as well as sometimes a junior member of a more senior team led by his superior. The question in his mind was how the self-made man would be able to find a way of doing this successfully.

Mr. Marsh had convinced them that excessive concentration on technological training could interfere with managerial development. The Institution already recognised this and Part III of the examination which qualifies for membership was wholly devoted to management subjects, technology being restricted to Part II. Nevertheless, should the Education Committee see whether even more ought to be done to enable men with technological skill to develop into good managers?

Mr. Marsh said that the companies to which he had referred earlier had come to the conclusion that it was easier to put technology into the broad arts man and let it be used sensibly, than to put liberality into the few technical people of character and ability at the top. Long years of technical training did something to a man from which it might be difficult to extricate him. This was the real challenge, and on this matter the great Institutions should get together. It was the association of all these disciplines that created the problem in the factory.

On the co-operation aspect, new professional bodies, with perhaps less exacting standards, were emerging; for instance, the Institute of Personnel Management, with 4,000 or 5,000 members out of a possible 20,000. The self-made man might bring in a specialist such as this, and possibly learn something from him as well. This sort of thing had been done in the aircraft industry, especially, since the War. Today one found the personnel manager dealing with this kind of thing, and with selection, not so much with the ordinary day to day administration and welfare processes for which he was trained. Thanks to the shortage of technologists he was playing a very different role. These days, when companies sought a personnel manager they had in mind the key men for the future—this was where the real shortage lay—and not on the shop floor. As yet there was not much co-operation between the professional bodies of the technological revolution and the managerial revolution.

Sir Walter Puckey (*Past President*), in moving a vote of thanks to Mr. Marsh, said that he had come to the platform, first, because any vote of thanks to a distinguished speaker should be tendered with the utmost dignity; secondly, because someone in the audience had challenged a self-made man to go on the platform. He thought that he might be classed as a self-made man.

After reading Mr. Marsh's Paper for the first time, he had felt himself to be a horrible example of unskilled labour. On reading the Paper the second time, he had been confirmed in that belief. It was a very good thing that this most interesting Paper on an important topic had been delivered, particularly under the aegis of the Institution, which might in a way be called a self-made Institution. Its parents certainly got together on the basis of unholy deadlock and it had certainly been born with very considerable labour. In its early years it had been brought up by men whose University had been the university of life. Most of them, including himself, came up—or jumped up—from the shop floor, so in many ways the Institution fitted the popular image of the self-made man, Institution-wise. Therefore, it was important that they should on occasion critically examine themselves as a body and as individuals.

He could not help feeling that at times they had lost sight of the purpose of the meeting. He wondered whether the net result of Mr. Marsh's remarks had been praise of the self-made man or condemnation? Was the self-made man an "organisation man" or a dis-organisation man? Was he a man who had not gone to a University? Believing, as they did on the whole, in the self-made man, might they not say that the ideal manager of the future might be one who had not gone to the University, just as many of our top men in industry today had not?

It had been interesting to hear raised the point that many of our technological courses were ironing out the individual, and the value of the individual. In many social institutions it sometimes seemed that the individual was being ironed out in favour of the organisation or the large group. Certainly, in technology, many of the feedback control devices were in danger of reducing the value of the individual. It was right to suggest that the Dip. Tech. scheme was helping to restore the balance. The tendency towards the organisation man meant that even stronger measures in favour of the self-made man would have to be taken in future.

Mr. John Marsh (left) receives from Mr. E. W. Hancock, O.B.E., Hon.M.I.Prod.E., Past President, a Georgian silver tankard as a memento of the occasion.

He was reminded of a well-known American—a man with considerable "fire in his belly" who had placed on the desk of all his executives the word "Think". One day he asked a junior employee what he thought of it and was told that there was a better word : "Listen". There was a lot of truth in that. The world was all the better for self-made men who were self-made men and who frequently imposed their will and thoughts upon other people. Also needed, however, were those who, when necessary, could face up to them and say, "Listen". As long as there were men with the necessary courage to do that, and others capable of generating that sort of reaction, we were not in too much danger one way or the other.

In paying tribute to the speaker, Sir Walter was reminded of the lines, well known to many :

Lives of great men all remind us
We must make our lives sublime,
And, departing, leave behind us,
Footprints on the sands of time.

The man they were honouring at this meeting had certainly left his mark on The Institution of Production Engineers. Mr. Hancock was no doubt delighted with the lecture and the discussion.

Mr. Marsh too had left his mark in the annals of the Institution. They had been delighted by his humour, his wisdom and his ability, and on behalf of The Institution of Production Engineers, Sir Walter thanked him most warmly.

Mr. E. W. Hancock, O.B.E., said that Sir Walter had been correct; this evening had been just what he had wanted. This was a country of very intelligent people, in which there had already been technical development. Once a year at least such people should be able, as it were, to inject a "flux" so that the technical and human sides would develop together. Tonight that had been done. It had been plain that the meeting did not believe that one worked only for riches. Income was but a small part of real wealth. He had been a manager for many years, responsible for never less than 12,000 people (he always counted the wives and families) and could realise what "riches" there were in working, not from the "fire in one's belly" but from the fire in one's heart and head. The technical "fires" and the inspiration to go ahead would continue, but he hoped that this great Institution would always pause and consider the need for the heart as well as the head.

Mr. Marsh had helped them tremendously in this and he hoped that he would always look back on this occasion as something that he had been pleased to do. Mr. Hancock said it was a wonderful thing for him to be at the reading of his Named Paper, and he was grateful to the Institution for allowing him to make the presentation to Mr. Marsh.

Mr. E. W. Hancock then presented Mr. Marsh with a silver tankard on behalf of the Institution.

Mr. Marsh, thanking the Institution, said it had been a memorable evening and he and his family would always treasure the memento, which he had been told was 213 years old.

The meeting terminated.

Special Notice

For a number of reasons it has been necessary to make a further change in the presentation date and the venue of the 1961 Lord Sempill Paper:

"THE WORLD'S FUTURE TRANSPORT REQUIREMENTS"

by Sir Percy Hunting

This meeting will now take place on THURSDAY, 25th JANUARY, 1961, in The Royal Aeronautical Society's new Lecture Theatre at 4 Hamilton Place, London, W.1, at 6.30 p.m. A form of application for tickets appears in the Supplement to this Journal.

THE POTENTIALITIES OF ACCURATE MEASUREMENT AND AUTOMATIC CONTROL IN PRODUCTION ENGINEERING

by Professor JOHN LOXHAM, C.G.I.A., M.I.Mech.E., M.I.Prod.E., M.B.I.M.

Head of Department of
Aircraft Economics and Production,
College of Aeronautics, Cranfield.

This Paper was presented at the Symposium on "Machine Tool Control Systems", organised by The Institution of Production Engineers and held at The College of Aeronautics, Cranfield, 24th-28th August, 1960.

IN considering the developments which are likely to take place by exploiting the potentialities of accurate measurement and automatic control in the field of production engineering, it is appropriate to examine the present state of knowledge against the background of technological development over a long period. Amongst the many criteria which may be used as the standard of measurement by which an assessment of man's progress can be made, consider the speed at which he has been able to propel himself over the surface of the earth.

The graph in Fig. 1 shows this development during the Christian era and from 1912 the value which is plotted is the official air-speed record. The chart shows that for about 1,700 years no progress was made and it was about the middle of the eighteenth century when small changes began to occur. The upward trend which began at this time was due to the development by James Watt of the steam engine, and the following extract from the diary of an English engineer, Richard Reynolds, dated October, 1760, provides a valuable record about the state of production engineering, and the machine tool industry in particular, at that time:—

"Began this day to scour the bore of a great cylinder of a fire engine for drawing the water from the

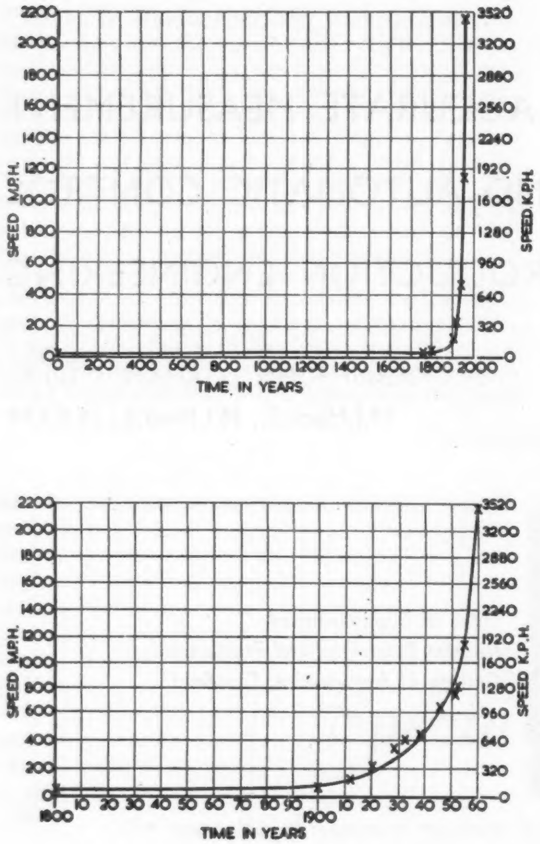


Fig. 1. Speed of travel from the year 1 A.D. to 1960 A.D.

coal pit at Elphinstone, of a bore 28 in. across, and in length 9 ft., the same being cast of brass and after much discouragement, and the spoiling of three before, which made us of much doubt if we could ever succeed in a task of such great magnitude; but being by reason of the extremity to which the Proprietors of the pit were at, having to employ more than 50 horses to discharge the water thereof, we were much urged to persevere, and we give great gratitude to Almighty God, who hath brought us through such fiery tribulations to an efficient termination of our arduous labours.

"Having hewed two baulks of deal to a suitable shape for the cylinder to lie therein solidly on the earth in the yard, a plumber was procured to cast a lump of lead of about three hundredweight, which being cast in the cylinder, with a dike of plank and putty either side, did make of it a curve to suit the circumference by which the scouring was much expedited. I then fashioned two iron bars to go around the lead whereby ropes might be tied, by which the lead might be pulled to and fro by six sturdy and nimble men harnessed to each rope, and by smearing the cylinder with emery and train oil through which the lead was pulled, the circumference of the cylinder on which the lead lay was presently made of a superior smoothness; after which the cylinder was turned a little, and that part made smooth, and so on, until with exquisite pains and much labour the whole circumference was scoured to such a degree of roundness as to make the longest way across less than the thickness of my little finger greater than the shortest way; which was a matter of much pleasure to me, as being the best that we so far had any knowledge of."

As one further examines the chart in Fig. 1, it is interesting to speculate on its shape during the next forty years. This will bring us to the end of the present century. It is probable that by 1970 the present world air-speed record of 2,150 miles per hour will have become the operating speed for supersonic air liners operating on a commercial basis on routes such as the "North Atlantic". When aircraft of this type are in operation it will be possible to fly from Europe to New York in about two and a half hours, which is less than the time taken to travel from the average place of residence to the appropriate International Airport, and to pass through the legislative and other formalities which appear to be an essential part of foreign travel. From this it would appear that when this speed becomes commonplace, there will be little benefit in endeavouring to obtain substantially higher values. As a further development of this point, consider the graph shown in Fig. 2. This shows the speed at which the 24-hour Le Mans Race has been won from 1906 when it was first initiated, to 1960 when it was won at an average speed of 110.5 miles per hour for the 24 hours, which is about two miles per hour slower than the speed at which the race was won in 1959. This graph also shows that there has been no significant change in the speed of the winning car over the past ten years. It is unlikely that there will be any further significant change during future years.

In considering the future development of equipment such as aeroplanes, motor cars and the many other products which have been created and brought to a high standard of efficiency during the present century, the trends shown in Fig. 3 become of some importance. The curve A shows the percentage improvement obtained by the introduction of a new model in relation to the equipment which it is designed to supersede, and the curve is following the law of diminishing returns. Instances will occur where, because of some important new development such as the jet engine superseding the piston engine for commercial aircraft, a large percentage improvement will be obtained. When these outstanding developments are viewed against a background of a long period of history it must be stated that the, too, will follow this same law of diminishing returns. This gradual mean trend in the direction of a smaller percentage improvement is inevitable because the greater the improvement obtained by any new model, the smaller is the amount of improvement available for exploitation in future designs.

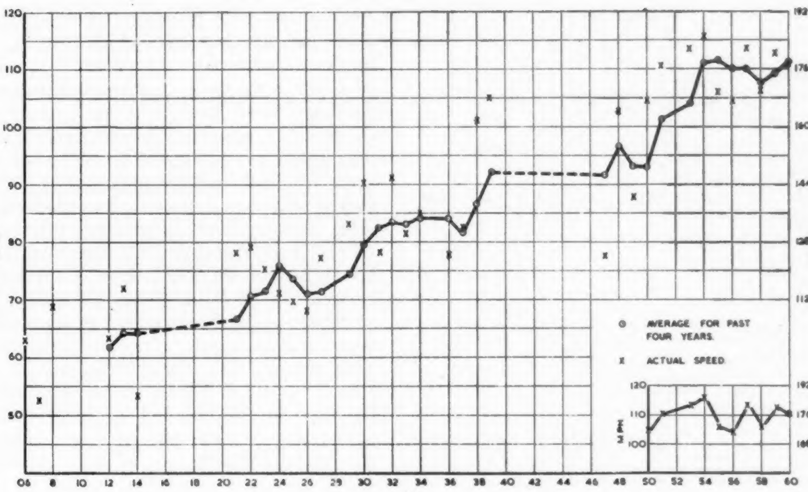


Fig. 2. Table showing average speed of winning car in 24-hour Le Mans Race from 1906 - 1960.

The second curve shows, on the same time basis, the cost of introducing a completely new model. The complexity of modern equipment, the high cost of its development and the high cost of modern tooling, makes the cost incurred by the introduction of a new model become increasingly higher as the years go by. This tendency is shown by curve B. When these two curves are examined in relation to each other for the years, say, 1920 to 1960, they show that for many of the products now in current production, the improvement obtained in relation to the money expended by the introduction of a new model in 1960 is small in relation to the benefit gained for the money expended in 1920.

During the past forty years the application of scientific knowledge to the creation and the improvement of many products has been overwhelmingly successful. The improvement obtained in relation to the money expended will be less in the future and this will cause designs to remain stable for a longer period than has been customary in the past. One further fact which emerges from this analysis is that while in the past it was satisfactory for a product to have a short life, because at the end of that short period of time it would be obsolete and require replacement, the slowing down of obsolescence will create a demand for a product which will stand up to service conditions for a longer period.

optimum standards of quality

It is against this economic background that we should examine what are the optimum standards of quality. The engineering industry, as a whole, has been slow to appreciate that the benefits of scientific investigation and analysis which have been used so successfully in many laboratories, can be applied with equal success in the machine tool and industrial engineering laboratory where the subject under investigation is the process of manufacture. In contrast to the work of the designer where most of the richest fruits have already been gathered, the process of manufacture is almost virgin territory and scientific workers operating in this field can make major contributions to technological progress during the next few decades.

If we are to produce highly efficient equipment we must, in the first instance, give the designer complete

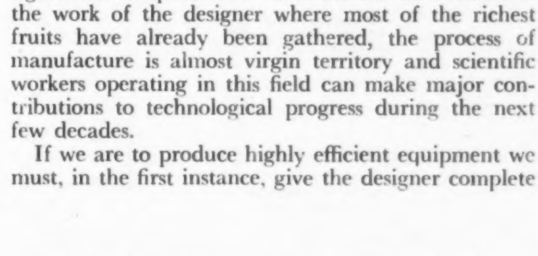


Fig. 3. Ratio of percentage improvement and cost incurred by introduction of new models.

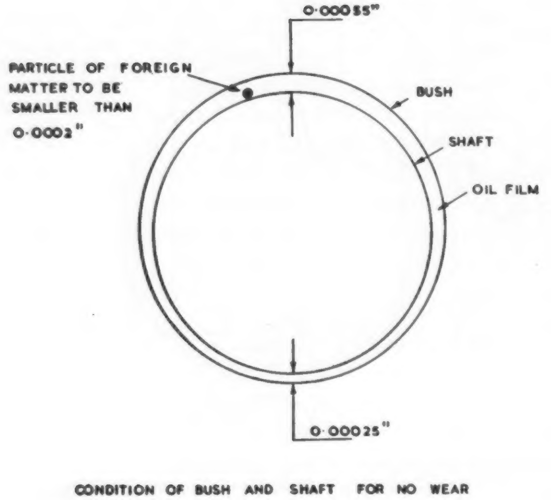


Fig. 4. Ideal fit of shaft in bush.

freedom to state precisely what is required to ensure that the mechanism which he is designing will function perfectly. Consider the simple problem of a shaft running at a predetermined speed and a predetermined load in a bush of one inch nominal diameter. Under the specified conditions of loading and speed it can be established that the ideal clearance for such an arrangement is 0.0008 in. in diameter and this is shown diagrammatically in Fig. 4. The arrangement illustrated provides a condition whereby the rotating shaft does not come into metallic contact with the bush, but is supported on an unbroken film of oil. If the lubricating oil is well filtered or other means are provided to keep the bearing clean, wear can be made almost insignificant over a very long period. The commercial aspect of this is illustrated in Fig. 5 which shows diagrammatically how, by the introduction of accurate measurement and automatic control and in some cases by increasing the manufacturing cost of the component parts by a small amount, a product which is of better value for money expended is produced.

In spite of this the designer must accept that it is not possible for all parts in an assembly to be made so that the ideal fit is obtained on all assemblies, and he must state clearly the magnitude of the variations from the ideal which he is prepared to tolerate.

In the case under review let it be assumed that he agrees to the clearance being reduced to 0.0005 in. and increased to 0.0015 in. With this as the technical basis for the selection of tolerances for the shaft and the bush, and, with a desire to give a slightly larger tolerance to the bush than the shaft, he would select

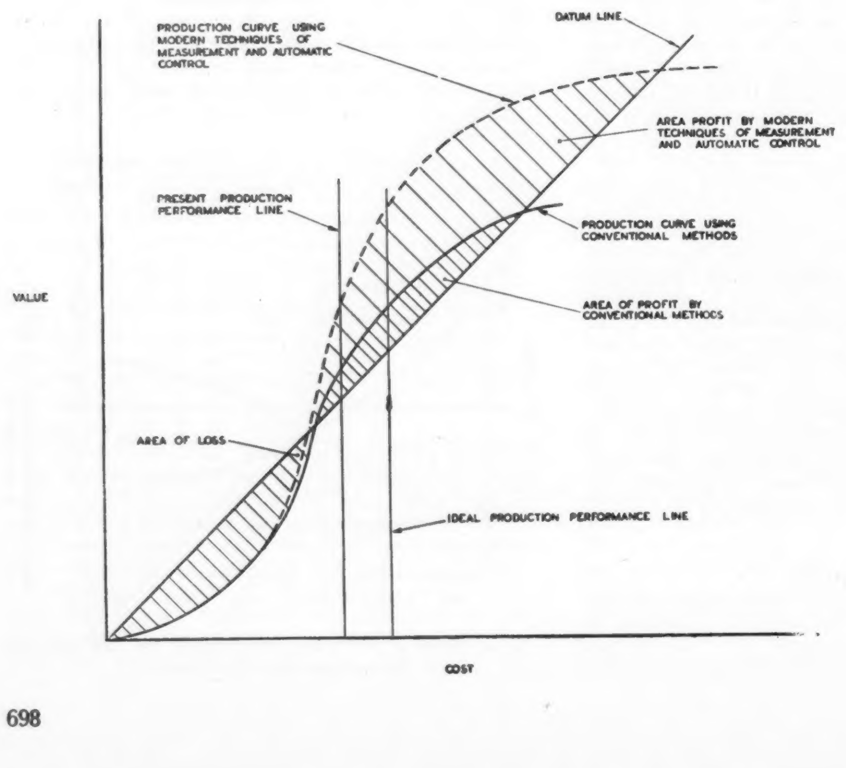


Fig. 5. Ratio of cost and value of product produced.

from British Standard 1916 the standard bush tolerance of 1 in. H 6 and the standard shaft tolerance of 1 in. f 5. These standard tolerances 1 in. H 6 $\left(\begin{matrix}1.0000\\1.0005\end{matrix}\right)$ and 1 in. f 5 $\left(\begin{matrix}0.9994\\0.9990\end{matrix}\right)$ provide a fit tolerance of 0.0006 in. to 0.0015 in. clearance, which is satisfactory because it is inside the boundary of variation which the designer agreed to tolerate. This is illustrated in Fig. 6, which also shows the ideal size of the hole as 1.0001 in. and the ideal size of the shaft as 0.9993 in. for the ideal fit of 0.0008 in. clearance. The operator responsible for the final machining of these parts should be encouraged to work as closely as possible to the ideal size and to look upon the boundaries of tolerance as danger posts from which he should keep a safe distance, because they indicate a size which has departed from the ideal by such a large amount that the part must be rejected.

Some production engineers will claim that if tolerances are considered on this basis, a series of designs will emerge which cannot be manufactured under normal production conditions. If normal production conditions are to be considered as giving to the machine operator fixed anvil plug and calliper gauges on which allowances for gauge makers' tolerance and gauge wear have been made, and these totally inadequate implements are the only means made available to the operator to enable him to assess the accuracy of the parts he is producing, it must be agreed that 0.0004 in. on a shaft and 0.0005 in. on a hole are very small tolerances. If, instead of this inefficient arrangement, full advantage is taken of the potentialities of accurate measurement and automatic control, the task becomes a relatively simple one.

example of an efficient production technique

Consider the production of the shaft to the tolerance of 1 in. f 5 $\left(\begin{matrix}0.9994\\0.9990\end{matrix}\right)$ as shown in Figs. 6, 7 and 8 with an ideal declared size of 0.9993. In the selection of the tolerance specification as set out above, care was taken to consider the situation created when the two parts are fitted together. To control the quality of mechanisms made from parts taken from a large group by random selection, it is necessary to control the distribution of size on all the important dimensions on the parts comprising the group. In the case under review it is desirable that the distribution of size on the 1 in. f 5 diameter shaft should be approximately as shown in Fig. 7. It is when this distribution pattern is known that the production engineer can select a production process which will give the type of size distribution which is at least equal to, and may be better than, the one required.

It is important that the production engineer of the future should plan to make the production process produce the parts so that they conform to this type of predetermined size distribution pattern. This will not only eliminate the need for a final 100% inspection but, far more important, it will ensure that a large percentage of the parts are manufactured near to the ideal size and a very few near to the size at which they will be rejected.

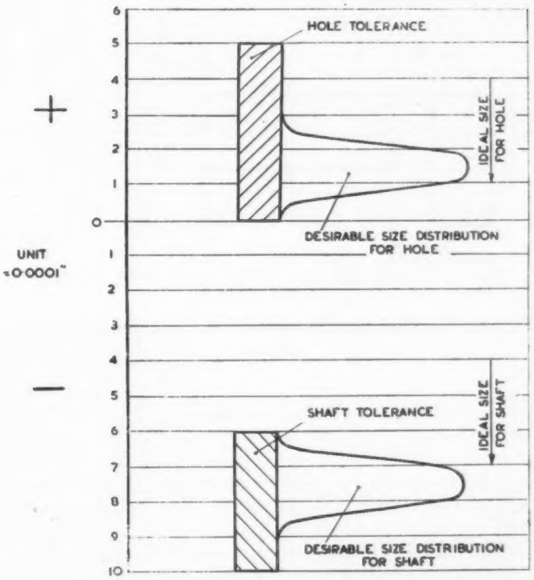


Fig. 6. Diagram showing fit between shaft and hole.

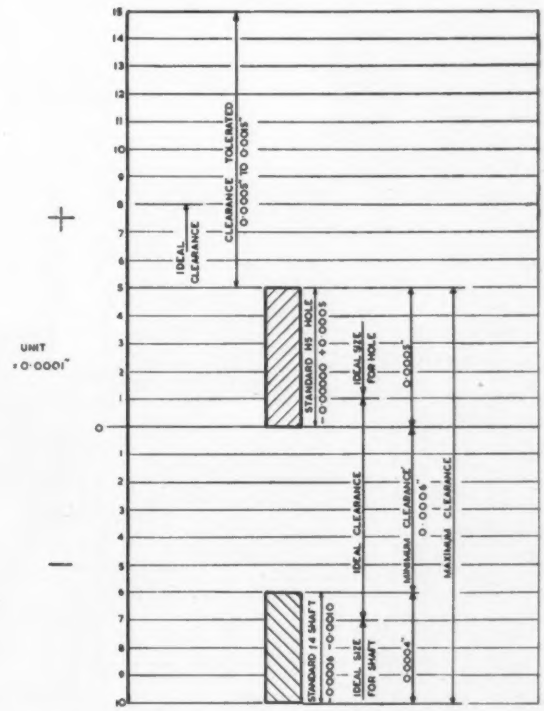


Fig. 7. Ideal size distribution for shaft and hole.

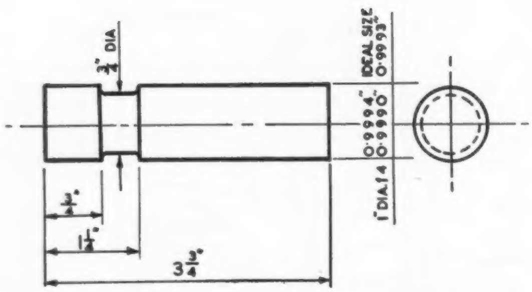


Fig. 8. Testpiece used in experiment on automatic control of size.

In the finish machining of the part shown in Fig. 8 to a tolerance of 0.9994 in. to 0.9990 in. with the ideal size of 0.9993 in., let it be assumed that the part will be ground on a cylindrical grinder from a turned size of H. 1.007 in., L. 1.004 in. The grinder should be fitted with a controller designed automatically to initiate the following programme of operations as illustrated in Fig. 9:

1. load part into machine and press operating button;
2. after rapid approach of wheel to work, machine operates on coarse in-feed and reduces part from size A to size B (Fig. 9);

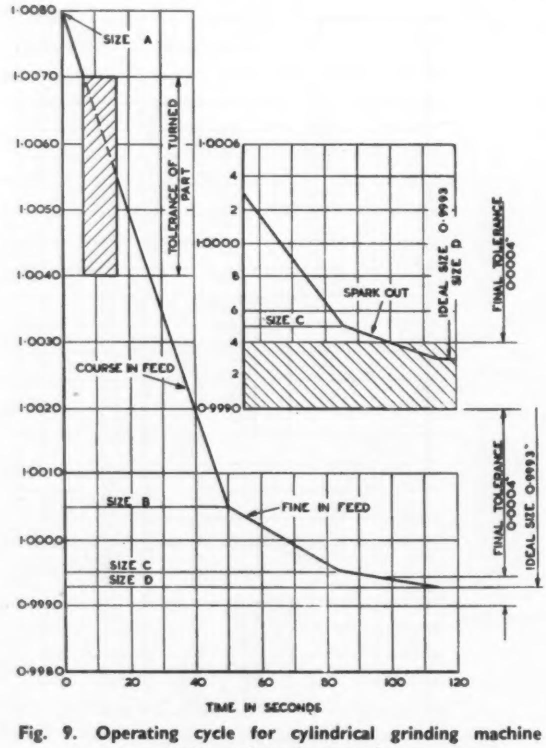


Fig. 9. Operating cycle for cylindrical grinding machine using automatic control.

3. when size B is detected machine changes automatically from coarse in-feed to fine in-feed;
4. machine reduces part by fine in-feed from size B to size C;
5. when size C is detected fine feed is automatically stepped;
6. machine reduces part during spark out operation from size C to size D;
7. when size D is detected grinding wheel is automatically retracted;
8. part is removed from machine.

The following tests were made to investigate if the target set in the case under review was attainable. The equipment responsible for withdrawing the grinding wheel when the correct size is detected consists of (a) a grinding gauge which is measuring the part during the grinding operation and (b) an automatic controller which, having received an impulse from the grinding gauge, will initiate the signal which retracts the grinding wheel. These two items of equipment were tested separately.

Fig. 10 illustrates the grinding gauge being tested to investigate the degree of inconsistency of behaviour when placed on a rotating work-piece twenty times, with coolant flowing on the part in the same way as would be applied during the grinding operation. The results of this test are shown in Fig. 11. The equipment used to investigate the degree of inconsistency in the controller when supplied with a gradually changing air pressure from an air valve of the same type as the one fitted in the grinding gauge, is illustrated in Fig. 12. A diagrammatic representation of the test rig and the results obtained in a series of twenty consecutive tests are shown in Fig. 13. The combined errors of these two items is well within ten millionths of an inch.

These results are not exceptional, but follow naturally from the application of simple scientific principles to a production problem. The attainment of tolerances of 0.0004 in. (400 millionths of an inch) on the basis of producing 80% of the parts to half this tolerance, and under normal production conditions making no scrap is, therefore, easily attainable. The grinding gauge, automatic controller and an automatic recorder used in a comprehensive test in the author's laboratory are illustrated in Fig. 14. Fig. 15 is a reproduction of the automatic record produced during the grinding of twenty consecutive parts. One division on the scale represents 0.0001 in. The degree of variation in the group of 20 parts is within 0.0001 in. and the floor-to-floor time cycle for this operation was 1.2 minutes. The diagram, Fig. 16, is a record produced automatically showing the size distribution on a group of 100 parts.

The majority of machine operators who are provided with the facilities just described and are given an attainable target, will co-operate in arranging to obtain the results which are required.

There are two simple and very important conditions which must be satisfied if the results obtained in the laboratory are to be obtained in the workshop under normal production conditions. They are:—

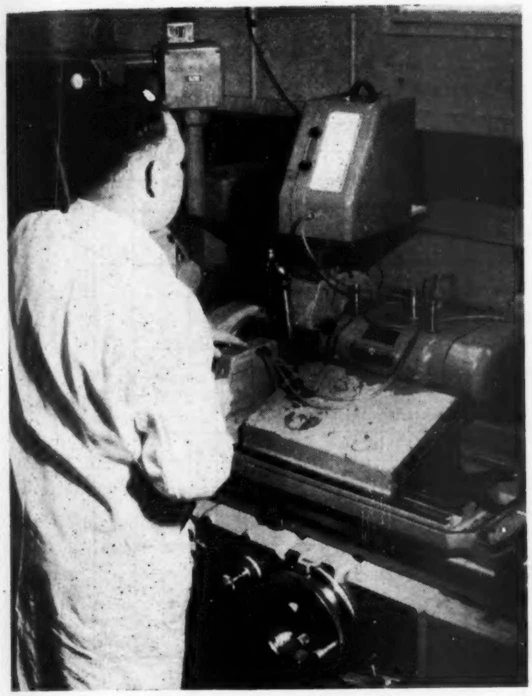


Fig. 10. Operator testing high precision grinding gauge.

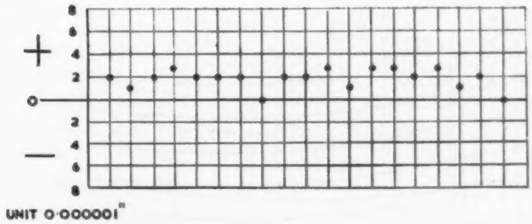


Fig. 11. Results of test on grinding gauge.

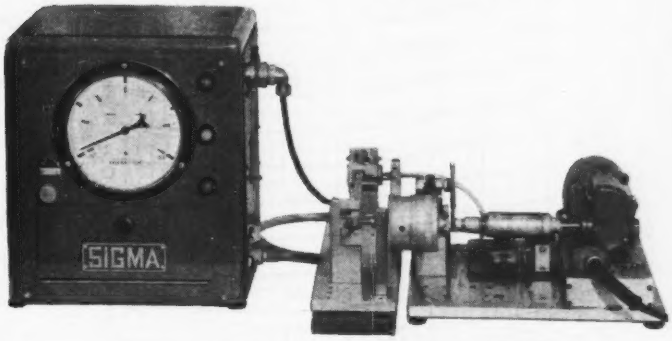
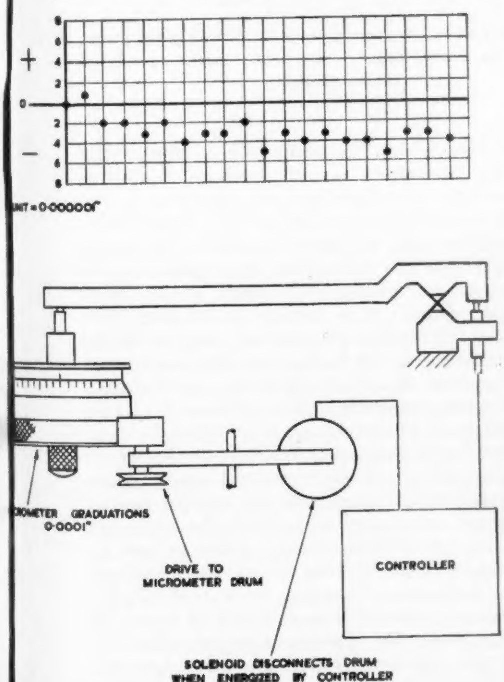
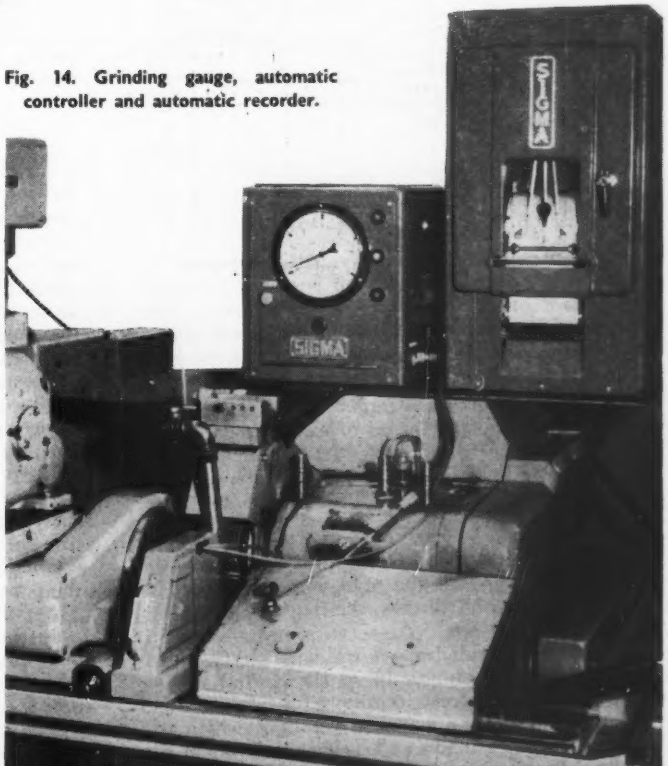


Fig. 12. Rig for investigating accuracy of automatic controller.



g. 13. Diagrammatic representations of test rig used to vestigate accuracy of automatic controller and results obtained from 20 consecutive tests.

Fig. 14. Grinding gauge, automatic controller and automatic recorder.



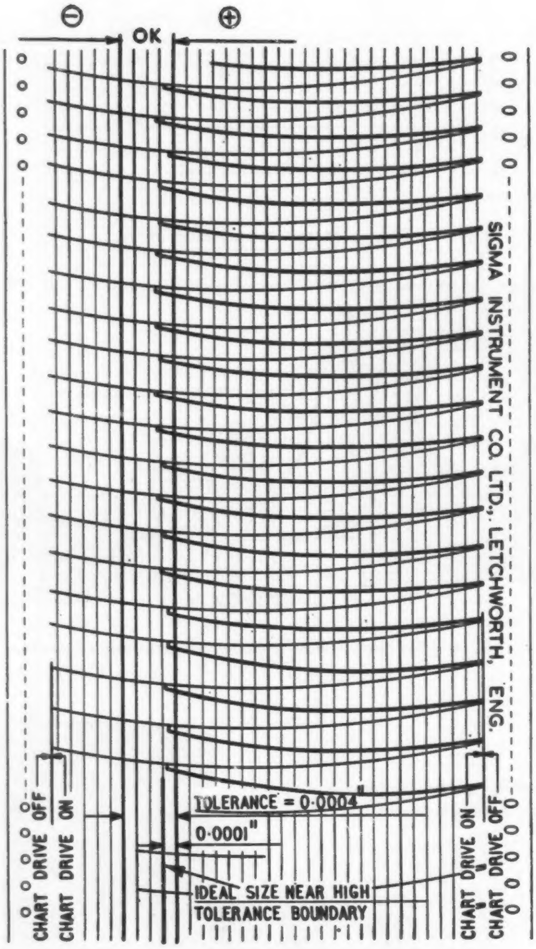


Fig. 15. Copy of record from automatic recorder.

1. Do not sacrifice easily attainable good quality by trying to reduce the production costs below what is desirable.
2. Give the operator a target which is attainable and give him the means of examining for himself and in considerable detail the extent to which he is attaining the target which has been set.

If full advantage is taken of this technique there will emerge a new type of craftsman who has the skill and, if we provide the right incentive—which is not only money, he will have the desire to attain the targets which are set.

The example quoted above has been developed in some detail in an endeavour to show what is considered to be the correct technique for establishing a tolerance and a manufacturing technique which will ensure parts being made well inside the limits of size which it has been agreed can be tolerated. There

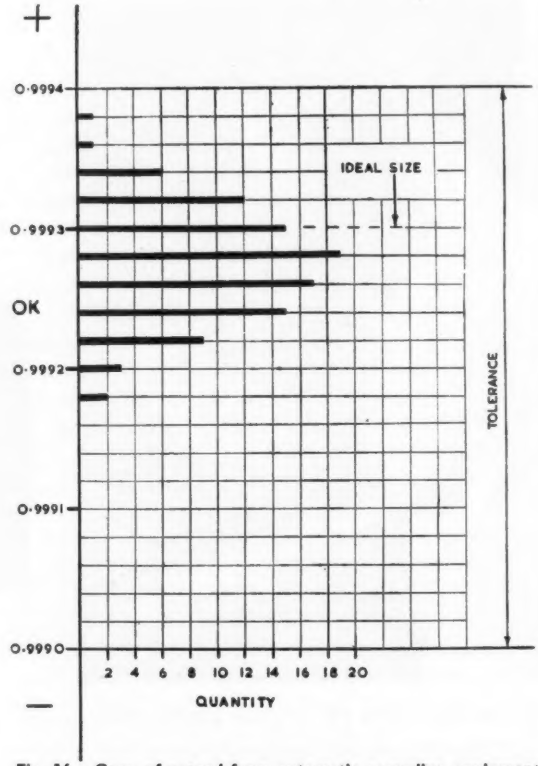


Fig. 16. Copy of record from automatic recording equipment showing size distribution on 100 parts produced consecutively.

are many cases where the procedure recommended for selecting tolerances would produce tolerances much wider than the value quoted, and it is in the interests of economic manufacture that these tolerances should be made as large as possible. There are other cases where the same procedure would result in the creation of tolerances very much smaller than the example quoted. It is natural to enquire how small can the tolerances be made for parts produced on a commercial basis. From the investigations carried out by the author, it appears that the size detecting devices becoming available enable tolerances of plus and minus ten millionths of an inch to be held on parts of one inch diameter. When this degree of accuracy is required the size detecting device is not the main criterion for accuracy, but careful control of temperature, geometric shape and the means of establishing a very accurate basis of size for use by the person engaged on the final machining operations. These three items are referred to later in the Paper.

In the example quoted above the size of each part was measured and the process stopped when the target size was detected. There are other grinding processes, such as through-feed centreless grinding, where it is only possible to detect the trend in the change of size and adjust the machine periodically to compensate for this trend which is usually due to

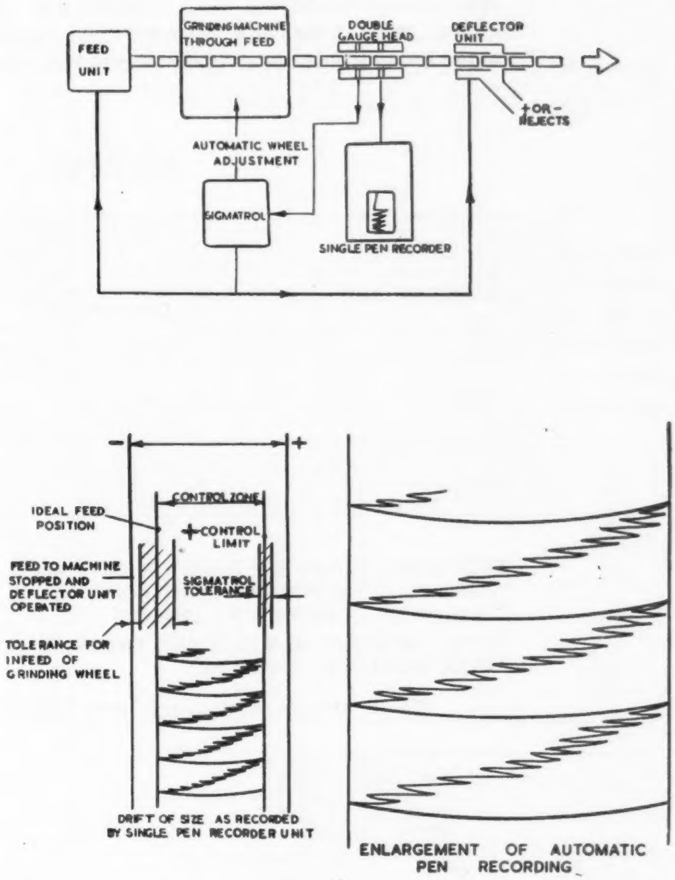


Fig. 17. Diagram of control and recording equipment fitted to through-feed centreless grinder.

wear of the grinding wheel. This technique is illustrated diagrammatically in Fig. 17. The value of using an automatic recorder is demonstrated in this diagram. Most engineers would assume that the size of 0.125 in. diameter needle rollers one inch long passing through a centreless grinder at 500 per minute, would increase in size at a uniform rate due to the gradual wear on the grinding wheel. The author expected this to happen, but the recording from the automatic recorder showed this was not so, and that superimposed on the approximate uniform wear was a pronounced wave pattern. This was analysed by increasing the speed of the chart in the recorder as shown on the right-hand side of the diagram. It is by analysing data of this type that a higher standard of performance in the field of engineering manufacture can be established. The results obtained from a test run with this equipment is illustrated in Fig. 18. All the parts produced during any one of the three settings of the machine are well inside the tolerance of 0.0001 in. and the majority are inside a tolerance of 0.00005 in.

The above theme could be developed further if required, but one doubts the need for this, because sufficient evidence is now available to show conclusively that the provision of control equipment which will send out the required signal when a predetermined size condition has been established is available. The main need now appears to be to develop a degree of co-operation between manufacturers of such equipment, the machine tool industry and the users of machine tools, which will enable this equipment to become integrated into the manufacturing process so that a high degree of reliability and confidence in the equipment and the technique can be established. So co-operation would be to the immediate benefit of everyone concerned. The high degree of repeatable performance easily attainable in many manufacturing processes by the techniques recommended has brought into prominence the importance of controlling temperature, geometric shape and establishing an accurate basis of size for use in setting the measuring device used for controlling the size of the final machining operations.

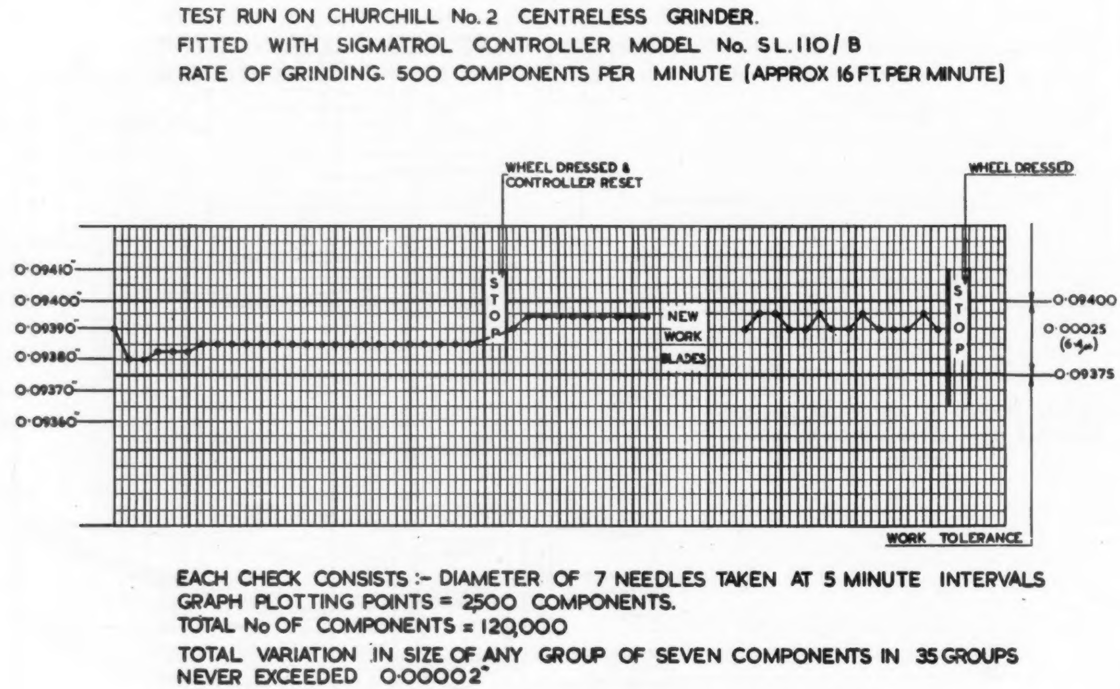


Fig. 18. Diagram showing size of parts produced on centreless grinder.

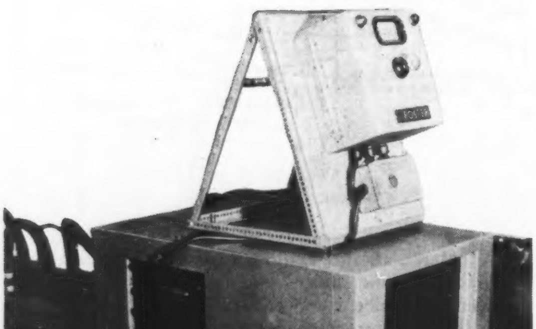


Fig. 19. Refrigerator unit with automatic controller used to control temperature of coolant on cylindrical grinding machine.

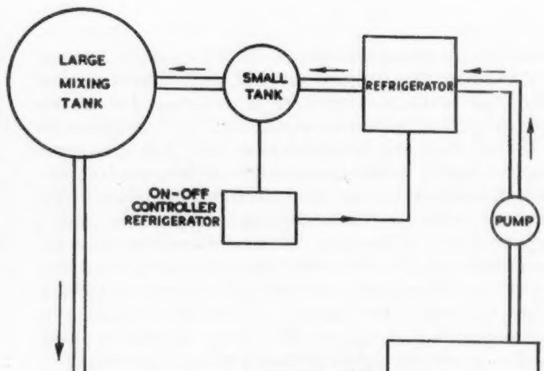


Fig. 20. Circuit diagram of coolant used on cylindrical grinder.

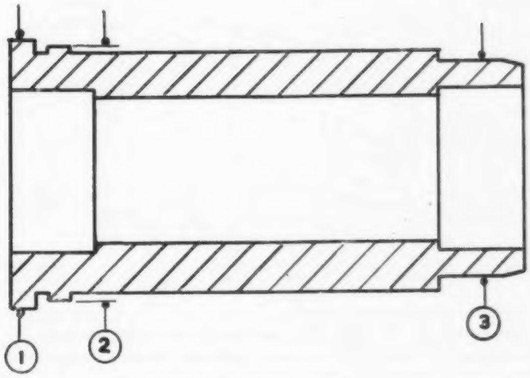
control of temperature

As the demand for accuracy increases, there has been created a demand for controlling the temperature of the part being produced during the particular manufacturing operation in which very accurate size control is required. The experiments carried out on the cylindrical grinding machine used in the above experiments provides an interesting example of how control of temperature can substantially increase the accuracy of the finished product. When the machine was used by the skilled operator shown testing the grinding gauge illustrated in Fig. 10, and the indicator shown was used to indicate when, by manual control, the part had been reduced to the correct size, it was possible to stop the grinding operation at the target dimension within plus and minus five millionths of an inch. When the grinding wheel and with it the coolant were withdrawn from the workpiece and the part became the same temperature as the room, the diameter changed by a reduction of size varying from −0.0001 in. to −0.00025 in. This error has been reduced to plus and minus ten millionths of an inch by adjusting the controller of the refrigerator unit, which is fitted in the circuit of the coolant supply, as shown in Figs. 19 and 20.

When tolerances of less than 0.0001 in. are required on work-pieces of approximately one inch diameter, it is desirable that the grinding machine be used in a room where the temperature is kept under close control or where the temperature changes at a very slow rate. The technique used for maintaining the coolant at the required temperature is to set the control switch shown in Fig. 19 so that when the grinding wheel, and with it, the coolant supply, is withdrawn from the workpiece the indicator attached to the grinding gauge, as shown in Fig. 10, shall continue to register the same size as was shown when the coolant was flowing over the work and, incidentally, over the measuring arms of the grinding gauge. For extreme accuracy and as a means of assisting in the control of geometric shape, it is desirable that in addition to the precautions described above a refrigerator unit should be incorporated in the circuits for the fluid in the hydraulic system and the lubricating oil. The refrigerator units for the hydraulic fluid and the lubricating oil should be adjusted so that these are maintained at the same temperature as the ambient temperature of the room in which the machine is installed.

If full temperature control is not possible the following technique may be used for the production of high precision parts which are seriously affected by temperature :

1. after turning, heat treatment, and preliminary stabilising, rough grind to dimensions shown in Fig. 21;
2. stabilise;
3. intermediate-grind to tolerances shown in Fig. 21;
4. after part has been in the standards room and at uniform temperature for a minimum of one day, make very careful measurements of each dimension requiring finish-grinding, and tabulate the results to the nearest 0.00001 in. as shown in Fig. 21;
5. place the part in the grinding machine and allow coolant to flow over the part as will occur during the finish-grinding operation; fit grinding gauge as shown in Fig. 10 and allow part to run as shown until for a period of 4 min. there is no observable change in size of the part as shown by the indicator;
6. set the indicator to read a value corresponding to the amount of metal to be removed as shown in Fig. 21;
7. very carefully, and without causing the part to increase in temperature, reduce the size of the part until the indicator reads zero;
8. repeat operations 6 and 7 for all other dimensions requiring finish-grinding;
9. transfer the part to standards room and after about 24 hours, when the part is at the standard temperature of the measuring room, inspect all important diameters.



Component		Setting Master made to nominal dimensions		
Dimension	Size and tolerance	Finish-grind size	Intermediate-grind tolerance	Rough-grind tolerance
1	4·622 4·620	4·621	4·6217 4·6215	4·628 4·626
2	4·372 4·370	4·371	4·3717 4·3715	4·378 4·376
3	4·278 4·276	4·277	4·2777 4·2775	4·284 4·282

Dimensions	Finish-grind size	Measured size	Metal to be removed
1	4·6210 0	4·6215 9	0·0005 9
2	4·3710 0	4·3716 2	0·0006 2
3	4·2770 0	4·2776 6	0·0006 6

Fig. 21. High precision setting master.

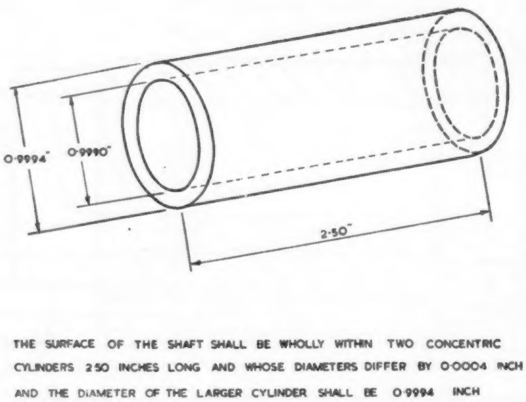


Fig. 22. Ideal cylinders representing boundaries of tolerance.

control of geometric shape

Only small reference can be made in the present Paper to the techniques which may be used for the control of geometric shape, but it must be said that machine tool spindles do not rotate about fixed axes and the slides of machine tools do not move along straight lines. The advent of accurate measurement and automatic control has created a situation where errors of form, which ten years ago were considered of little commercial importance because they were a small percentage of the total work tolerance, are now of paramount importance. They are, in fact, preventing the attainment of the small tolerances which have always been necessary and which, apart from errors of form, could now be achieved with ease and very little additional cost. The machine tool industry must examine this problem at once and in detail.

The scientific analytical investigation which this Paper is designed to encourage can make a major contribution to the solution of this increasingly important problem. As one example of what can be achieved, Fig. 30 shows an internal measuring machine, the slide of which is supported on a film of high pressure air 0.0004 in. thick. The mating parts of this slide contain errors of straightness of 0.0002 in. but the integrating effect of the 0.0004 in. thick air film provides a guide which causes the slide to move along a line which is straight to within 0.00002 in. over four inches.

The need to apply a strict control over geometric shape necessitates a reassessment of the methods used for applying tolerances to this increasingly important characteristic of geometric shape. The boundaries of tolerance for the cylindrical part as shown in Fig. 8 could be interpreted as illustrated by Fig. 22. The inspection of a part to the conditions specified in Fig. 22 is a very complicated process and under normal commercial conditions is impracticable. The method known as the "Taylor Principle" after its originator, W. Taylor of Leicester, England, is an attempt to satisfy this condition. This principle states that a full form gauge, which in the case under consideration would be a ring gauge, shall be used for the maximum metal condition and a two point gauge, which in this example would be a caliper gauge, shall be used for the minimum metal condition. The Taylor principle is not satisfactory for some applications for the following reasons:

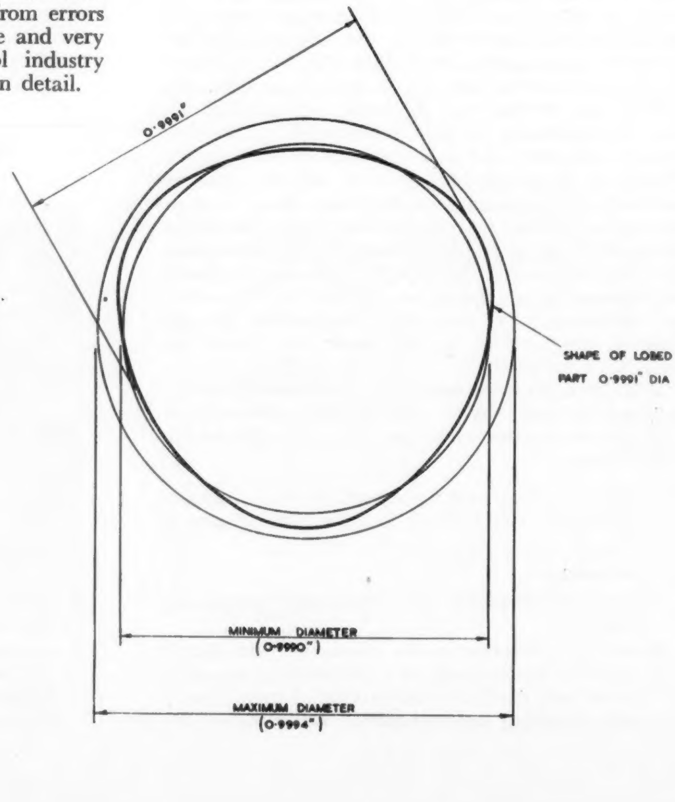
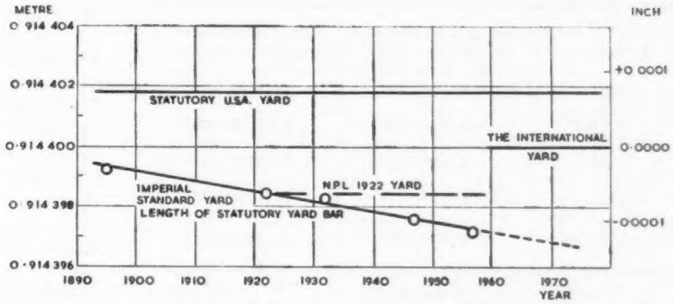


Fig. 23. Lobed figure of a type acceptable when inspected by the Taylor principle but outside the tolerance boundaries as defined in Fig. 22.

Fig. 24. International Standard Yard.



THE VALUES OF THE BRITISH, U.S.A. AND NEW INTERNATIONAL YARDS
(The Canadian yard was defined as 0·9144 metre in 1951)

1. there would be considerable difficulty in manufacturing the long ring gauges to the very high standards of accuracy which would be required;
2. the diagram Fig. 23 shows that the surface of a lobed part could be outside the boundaries of tolerance as shown by the ideal cylinders, but inside the tolerance as inspected by the Taylor Principle of inspection;
3. the operating conditions of some mechanisms require separate and very small tolerance for geometric shape in addition to a much wider tolerance for mean size.

In contrast to the above there are many parts on which the tolerance which is stated for diameter is not intended to satisfy the Taylor Principle, or the boundaries of tolerance as shown by Fig. 22.

A detailed examination of all the circumstances, arising mainly from the increased tendency for designers to specify small tolerances, indicates that where the control of geometric shape requires the introduction of the Taylor Principle or some more exacting method of control, this should be stated on the drawing.

When the requirements for geometric shape are known, it will be possible for the machine tool industry to produce machine tools which will manufacture parts which will satisfy the specification. This will necessitate the introduction of new types of slides and spindles, the operating principles of which are already known. The inspection of errors for geometric shape may be a long and, in some cases, a complex operation, but it seems probable that under normal conditions it will only be necessary to carry out a small percentage inspection on these features.

settlement of disputes

The system of limits and fits used in the majority of the metric using countries throughout the world are based on a document known as Bulletin 25 which was issued in 1936. This comprehensive publication provides tolerances suitable for a very wide range of applications and in addition makes recommendations on gauge tolerances and methods of gauging. The purpose of these detailed recommendations was an attempt to overcome some of the difficulties associated with the problem of declaring the time size of parts whose size was known to be very near the boundaries of the tolerance zone, and whose assumed size may be the subject of a dispute between the supplier and the customer.

The information on gauging methods as set out in Bulletin 25 has been of considerable value over many years and in the revision of the standard now being carried out these recommendations are being subject to critical re-examination. This detailed survey includes amongst other things a consideration of what contribution can be made to this problem by modern measuring techniques.

If a representative group of parts manufactured under normal production conditions are inspected on several features for size and geometric shape, it will be found that it is the errors of geometric shape and not errors of measurement which prevent the size of the feature being declared as a single dimension. It is against this background that a reassessment should be made of the significance of the boundaries of tolerance selected by the designer. What he requires in the majority of cases is a satisfactory fit between two mating parts. He is much more likely to obtain this if, in addition to indicating the precise boundaries of tolerance which he has selected from a table of standard tolerances where the values available increase in steps of approximately 60%, he also requests that some control be exercised over the size distribution in the parts comprising the group under consideration. From a technical standpoint, it is indisputable that if the size distribution is satisfactory and the majority of the parts are near the ideal size, with very few near the size at which they would be rejected—and the same conditions apply to the mating parts into which the inspected components will fit—more latitude can be allowed than would be desirable if the size distribution showed a large percentage of the bulk supply near the tolerance boundaries. If the customer is desirous of obtaining an accurate assessment of the quality of a group of parts which have been supplied, he is recommended to proceed as follows:

1. inspect a large sample of parts by manual, semi-automatic, or fully automatic means and obtain a size distribution diagram of the type shown in Fig. 16, and at the same time segregate those parts whose size appears to be within 10% of the tolerance boundaries;

Date	Value of Imp.-Std. yard expressed in mm.	Value of one inch expressed in mm.
1895	914·3992 08	25·3999 78
1922	914·3984 16	25·3999 56
1932	914·3982 00	25·3999 50
1947	914·3975 16	25·3999 31
1959	914·4000 00	25·4000 00

TABLE I
METRE-YARD RELATIONSHIP

2. re-inspect the small number of segregated parts with care and thoroughness for size and for geometric shape;
3. from the detailed information obtained from (2) decide which parts can be accepted and which rejected.

When considering the difficult decision to be made in (3), it is unlikely that errors of measurement will be considered of any significance. The much more difficult problem will be to act wisely from examining the complex data presented. Just as in a court of law complex problems require wisdom for settlement of guilty or not guilty so it is in metrology; rules alone cannot solve this problem.

the basis of size

By Act of Parliament passed in London in 1878, the Imperial Standard Yard was, and still is, defined as the distance between two fine lines scribed on gold inserts pressed into a bronze bar, it being specified that the bar must be supported in a specified manner and maintained throughout at a specified temperature. The Act also required that the yard should be remeasured every ten years and the new size thus established be accepted as the new Imperial Standard Yard. The reason for specifying that the yard be remeasured every ten years was that it was thought that because of improved methods of measurement, the new size thus established would be a more accurate assessment of the true size than was obtained by earlier measurements.

The chart shown in Fig. 24 illustrates that the errors in measurement during the past 50 years have been very small, and that a much more serious problem has been the magnitude of the continuous change which has taken place in the length of the Standard Yard during the period 1895 to 1958. This chart also shows that the length of the American Yard is greater than the Imperial Standard Yard, and the new International Yard is about midway between the British and the American standards.

The International Prototype Metre was established in 1880. It is made from 90% platinum, 10% iridum alloy, and measurement of its length by reference to the wavelength of monochromatic light shows that it has remained remarkably stable during a period of about 50 years. The situation thus created, where the Imperial Standard Yard was changing in length at a uniform rate while the International Prototype Metre was remaining remarkably stable, not only altered the declared size of the Imperial Standard Yard but also the Yard-Metre relationship, as shown by Table 1. The National Physical Laboratory took note of this difficulty in 1932 and from 1922 has used the size of the yard as established by the measurement of that year for the certification of all measurements required for science and technology from that date to the 1st July, 1959.

The problem of accurately maintaining international uniformity in length measurements was further complicated by the difference in size between the American and British yard. This difference has caused considerable inconvenience in countries such as Australia and Canada, where some firms were likely to purchase slip gauges for reference purposes from Great Britain, while other firms in the same countries would purchase their standards for reference purposes from the United States of America. These difficulties caused Canada to anticipate the adoption of the International Yard, and in 1951 she adopted the conversion factor for the yard as one yard being equal to 0.9144 metre, as shown in Fig. 24. The International Yard has now been established in the following terms by the six participating countries, and its adoption has helped considerably in obtaining international agreement on matters where high standards of measuring accuracy are required.

the yard and the pound for science and technology

"The Directors of the following Standards Laboratories :—

Applied Physical Division, National Research Council, Ottawa, Canada;
Dominion Physical Laboratory, Lower Hutt, New Zealand;
National Bureau of Standards, Washington, United States;
National Physical Laboratory, Teddington, United Kingdom;
National Physical Research Laboratory, Pretoria, South Africa;
National Standards Laboratory, Sydney, Australia;

have discussed the existing difference between the values assigned to the yard and to the pound in different countries. To secure identical values for each of these units in precise measurements for science and technology, it has been agreed to adopt an international yard and an international pound having the following definitions :—

The International Yard equals 0.9144 metre;
The International Pound equals 0.453 592 37 kilogramme.

It has also been agreed that, unless otherwise required, all non-metric calibrations carried out by the above laboratories for science and technology on and after 1st July, 1959, will be made in terms of the international units as defined above or their multiples or submultiples.

The above announcement was made concurrently by all the laboratories listed above.

A further development of the above standardisation is the international standardisation of the wavelength of certain monochromatic sources of light. It has been agreed internationally that one metre shall equal 1,650,763.73 times the vacuum wavelength of the orange, red radiation of the single isotope of Krypton of atomic mass 86.

basis of size in engineering organisations

The basis of size used by the majority of the engineering organisations is an end gauge usually referred to as a slip gauge. A very accurate measuring technique has been developed and perfected by the National Physical Laboratory for comparing the size of slip gauges having end measuring faces with the recognised international line standards. It is also possible by interferometry to determine the distance between the end faces of slip gauges by direct measurement to a declared accuracy of one millionth of an inch or one part in two million, whichever is the greater, and in these calculations the size is estimated to about 1/10th of this figure.

The establishment of the International Yard with the resulting uniform conversion between the metre and the yard, and the use of the wavelength of light as a fundamental and direct means of measuring the size of high precision slip gauges, provides the means whereby a highly accurate basis of measurement in both metric and inch sizes can be provided without difficulty in any part of the world. The type of instrument which may be used for this basic and fundamental measurement by means of interferometry where the wavelength of light is the only measuring medium is illustrated in Fig. 25. The degree of accuracy which is attainable by using this technique on a normal commercial basis may be judged by the data given in the chart shown in Table 2. This schedule records the errors in millionths of an inch, declared by the National Physical Laboratory to exist in a set of 81 slip gauges purchased commercially in the normal manner, and made to inch sizes by a firm in a metric using country.

TABLE 2

Errors in Set of 81 Slip Gauges measured in a Central Position and at 20°C (68°F). Unit of Measurement in Millionths of an Inch

Nominal Size	*Error*	*Nominal Size*	*Error*	*Nominal Size*	*Error*
in.		in.		in.	
0·1001	+1	0·119	+1	0·146	+2
0·1002	+1	0·120	+2	0·147	+1
0·1003	+1	0·121	−1	0·148	+1
0·1004	0	0·122	+1	0·149	0
0·1005	0	0·123	0	0·05	0
0·1006	0	0·124	+2	0·1	−2
0·1007	+1	0·125	0	0·15	+1
0·1008	0	0·126	0	0·2	0
0·1009	0	0·127	−1	0·25	+2
0·101	+1	0·128	+1	0·3	+2
0·102	+1	0·129	+2	0·35	+1
0·103	+1	0·130	0	0·4	0
0·104	+2	0·131	+3	0·45	0
0·105	+2	0·132	+3	0·5	+2
0·106	+1	0·133	0	0·55	+1
0·107	+2	0·134	−1	0·6	+3
0·108	0	0·135	+1	0·65	+1
0·109	+1	0·136	+1	0·7	+2
0·110	+1	0·137	0	0·75	+5
0·111	0	0·138	+2	0·8	+2
0·112	0	0·139	+1	0·85	+3
0·113	+1	0·140	+1	0·9	+2
0·114	0	0·141	+1	0·95	+5
0·115	+2	0·142	+2	1	+5
0·116	+1	0·143	0	2	+28
0·117	+2	0·144	0	3	+36
0·118	0	0·145	+1	4	+34

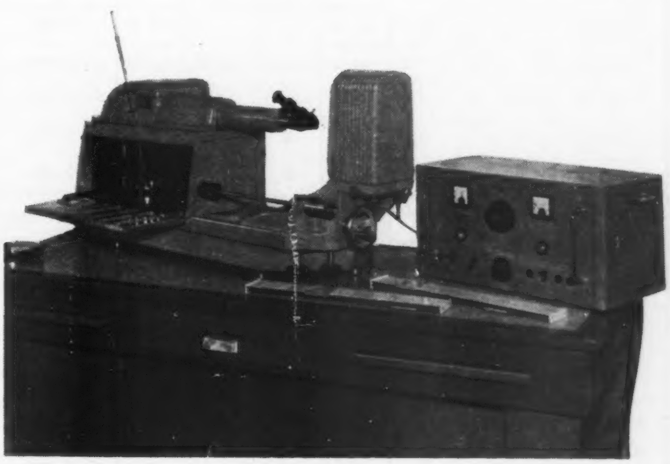


Fig. 25. Interferometer for determination of size on slip gauges.

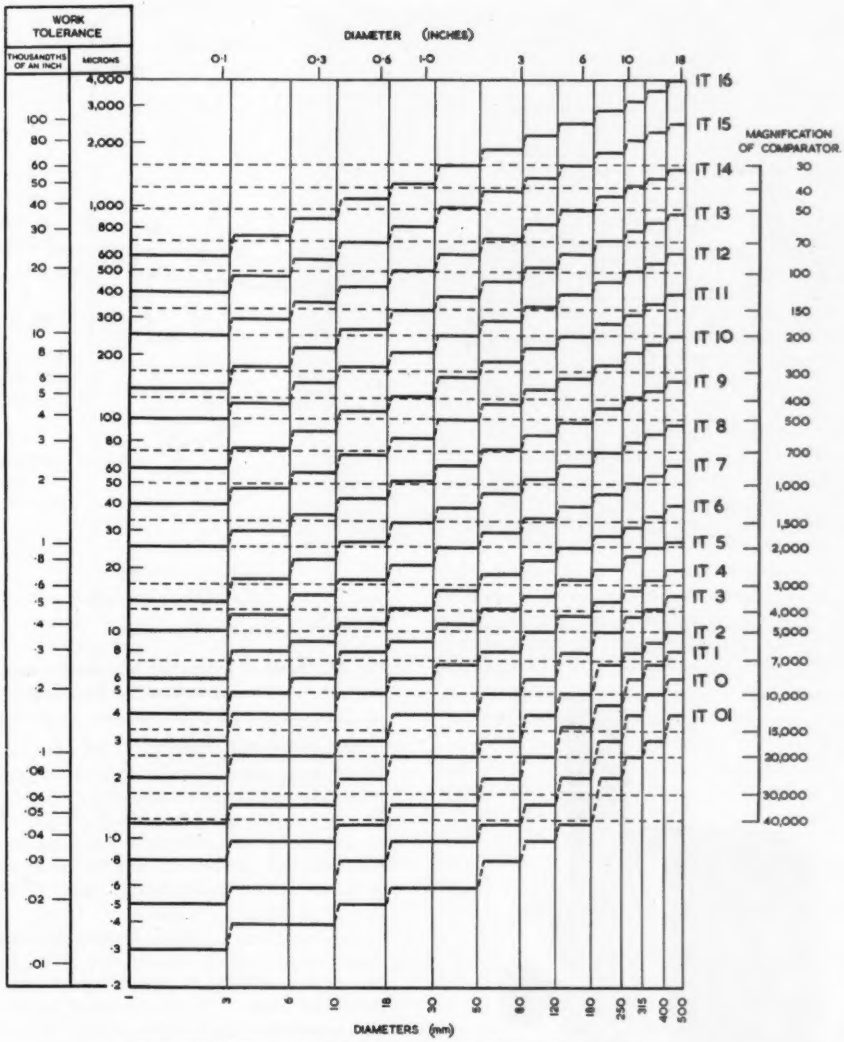
TABLE 3

RECORD OF CALIBRATION OF SLIP GAUGES

Unit of error in millionths of an inch
Tabled from N.P.L. Certificates

Box No. K52

Calibration Dates	Oct. 1939	Oct. 1944	May 1948	Sept. 1951	Nov. 1953	Aug. 1955	Calibration Dates	Oct. 1939	Oct. 1944	May 1948	Sept. 1951	Nov. 1953	Aug. 1955
Nom. Size	E	R	R	O	R	S	Nom. Size	E	R	R	O	R	S
0·1001	+ ·5	+1·0	+1·0	+1·0	+1·0	0	0·132	0	0	−1·0	0	0	−1·0
0·1002	+1·0	+2·0	+2·0	+1·0	+1·0	+1·0	0·133	+2·0	+1·0	+1·0	+1·0	0	0
0·1003	+1·0	+1·0	0	0	0	0	0·134	0	+1·0	0	0	−1·0	−1·0
0·1004	0	0	−1·0	0	−1·0	0	0·135	+2·5	+2·0	+2·0	+2·0	+1·0	+1·0
0·1005	+ ·5	0	0	−1·0	−1·0	−1·0	0·136	+ ·5	−1·0	−2·0	−1·0	−1·0	−1·0
0·1006	+ ·5	+1·0	0	0	−1·0	−1·0	0·137	+2·0	−1·0	0	+1·0	+2·0	+1·0
0·1007	+2·0	+2·0	+3·0	+2·0	+1·0	+1·0	0·138	0	−1·0	−2·0	−1·0	0	−1·0
0·1008	+ ·5	0	0	0	−1·0	−1·0	0·139	− ·5	0	−1·0	−1·0	0	−1·0
0·1009	+ ·5	0	0	0	−1·0	−1·0	0·140	−1·5	0	−2·0	−2·0	−1·0	−2·0
0·101	− ·5	0	−1·0	−1·0	−1·0	−1·0	0·141	+1·0	+2·0	0	+1·0	+2·0	+1·0
0·102	+ ·5	0	0	0	0	0	0·142	−4·0	−3·0	−5·0	−4·0	−4·0	−4·0
0·103	+1·5	+2·0	+2·0	+1·0	+1·0	+1·0	0·143	+ ·5	+2·0	−1·0	0	0	0
0·104	0	+1·0	0	0	0	0	0·144	+1·5	+2·0	0	+1·0	+1·0	+1·0
0·105	+2·0	+2·0	+1·0	+2·0	+1·0	+1·0	0·145	0	+1·0	−1·0	−1·0	0	−1·0
0·106	−2·0	−2·0	−3·0	−2·0	−3·0	−3·0	0·146	+2·0	+3·0	+1·0	+2·0	+2·0	+1·0
0·107	0	0	−1·0	0	0	−1·0	0·147	+1·5	+2·0	+2·0	+1·0	+1·0	+1·0
0·108	+ ·5	+1·0	+1·0	0	0	0	0·148	+1·5	+2·0	+1·0	+1·0	+1·0	+1·0
0·109	− ·5	0	0	−1·0	0	−1·0	0·050	+1·5	+3·0	+2·0	+2·0	+1·0	+1·0
0·110	− ·5	0	−1·0	−1·0	−1·0	−2·0	0·100	+1·5	+2·0	+1·0	+1·0	+1·0	+1·0
0·111	0	0	+1·0	0	−1·0	0	0·150	+ ·5	0	0	0	0	0
0·112	+1·0	+1·0	+2·0	0	0	0	0·200	+1·5	+1·0	+1·0	+1·0	+1·0	+1·0
0·113	+2·0	+2·0	+2·0	+1·0	+1·0	+1·0	0·250	+1·0	+1·0	0	+1·0	+1·0	0
0·114	+ ·5	+1·0	+3·0	+1·0	0	+1·0	0·300	+ ·5	+1·0	+1·0	0	0	0
0·115	+1·0	+2·0	+2·0	+1·0	0	0	0·350	− ·5	0	−1·0	0	−1·0	−1·0
0·116	0	+1·0	+2·0	0	−1·0	0	0·400	+2·0	+2·0	+1·0	+1·0	+1·0	+1·0
0·117	− ·5	0	+2·0	−1·0	−1·0	−1·0	0·450	−3·0	−2·0	−3·0	−2·0	−3·0	−3·0
0·118	−1·0	−1·0	−1·0	−2·0	−2·0	−2·0	0·500	+4·5	+6·0	+7·0	+8·0	+8·0	+8·0
0·119	− ·5	−1·0	0	−1·0	−1·0	−1·0	0·550	− ·5	0	−1·0	0	0	−1·0
0·120	0	0	0	0	0	0	0·600	−1·0	0	−1·0	0	−1·0	−1·0
0·121	+ ·5	0	+1·0	0	0	0	0·650	0	0	−1·0	0	0	0
0·122	+3·0	+2·0	+2·0	+2·0	+2·0	+2·0	0·700	+ ·5	+1·0	−1·0	+1·0	+1·0	0
0·123	− ·5	−1·0	−1·0	−1·0	−1·0	−1·0	0·750	−2·5	−2·0	−3·0	−1·0	−2·0	−2·0
0·124	+ ·5	0	0	−1·0	−1·0	0	0·800	+1·5	+2·0	+1·0	+2·0	+1·0	+1·0
0·125	+1·0	0	+1·0	0	0	0	0·850	0	0	−1·0	+1·0	0	0
0·126	0	−1·0	0	−1·0	−1·0	−1·0	0·900	−2·0	−1·0	−3·0	−1·0	−2·0	−1·0
0·127	+ ·5	+1·0	0	0	0	0	0·950	−1·0	0	0	+2·0	+1·0	+1·0
0·128	+ ·5	+1·0	−1·0	0	0	0	1·000	0	0	+4·0	+3·0	+4·0	+4·0
0·129	+1·5	0	0	+1·0	+1·0	0	2·000	+1·0	−1·0	+4·0	−1·0	0	0
0·130	+ ·5	−1·0	−1·0	−1·0	0	−1·0	3·000	+6·0	+2·0	+2·0	+1·0	+3·0	+3·0
0·131	+1·0	0	−1·0	0	0	0	4·000	−1·0	−8·0	−2·0	−3·0	−3·0	−1·0

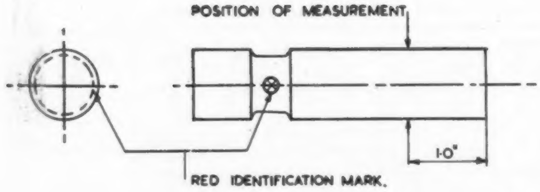


Note:- For diameters ≤ 1mm and grades up to IT 11 the tolerances are the same as for the > 1 to 3mm range

SUITABLE MAGNIFICATIONS OF COMPARATORS FOR CHECKING WORKPIECES MADE TO THE ISO SYSTEM OF LIMITS AND FITS.

Fig. 26.

The chart shown in Table 3 illustrates the original errors and the magnitude of the changes which have taken place in a set of 81 slip gauges which have been in constant use for the purpose of certifying the size of other slip gauges during the period October, 1939, to August, 1955. This set of gauges has been examined by the National Physical Laboratory on six separate occasions and the data obtained from these examinations is summarised in the table. The degree of reliability that can be expected from a set of slip gauges kept solely for the purpose of certifying secondary sets of gauges can be obtained from a detailed study of the data in the table. In the 462 measurements made on gauges below 1 in., the 12 measurements marked with a bold rectangle show that during periods varying between 2 and 5 years, one gauge changed three millionths of an inch, 6 have changed two millionths and 5 have changed one and a half millionths. The remaining 450 measurements show that during these relatively long periods the changes due to wear, structural transformations in the material, and errors of measurement during calibration have resulted in the declared changes of size between two consecutive measurements being a



IDEAL SIZE	MEASURED ERROR	+ TOLERANCE FROM IDEAL SIZE	− TOLERANCE FROM IDEAL SIZE
0·9993"	0·00005"	0·00010"	0·00030"

Fig. 27. Setting master for parts produced in experiments described in the Paper.

maximum of one millionth of an inch. In addition, the 1 in. gauge is recorded as having changed four millionths of an inch in four years, the 2 in. gauge three millionths in four years, the 3 in. gauge four millionths in five years and the 4 in. gauge seven millionths in five years.

Table 3 also shows that the changes in size which may be expected to occur over a period of years is not always a reduction in size due to gauge wear. Certain gauges have increased in size and this alteration is probably due to changes in the internal

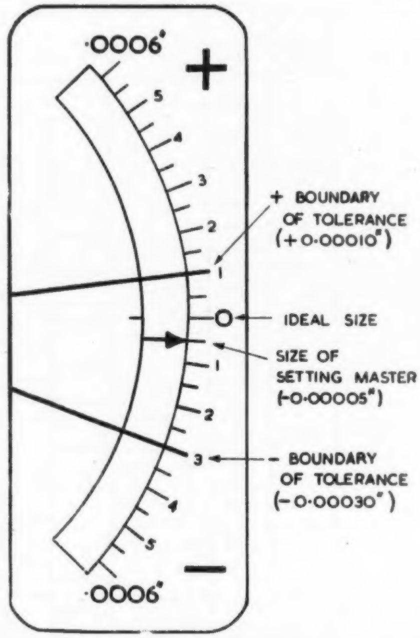


Fig. 28. Scale of measuring instrument used to inspect parts described in the Paper.

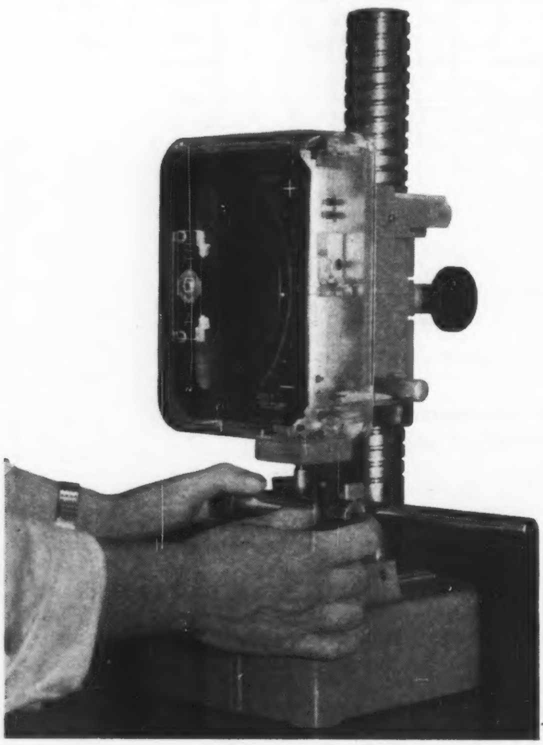


Fig. 29. Measuring instrument fitted with back-stop used to inspect parts whose manufacture is described in the Paper.

structure of the material. This evidence must not be taken as a reliable indication that structural changes in a material always cause the part to increase in size. In the case of the Imperial Standard Yard, as shown in Fig. 24, the structural changes in this material have caused the bronze bar from which the standard is made to become shorter and at a uniform rate during a period of about 50 years.

Any engineering organisation desiring to undertake manufacture on a universally interchangeable basis can expect to obtain reliability at least equal to that recorded above. The improved facilities which are now available, and others which are likely to become available in the near future, will provide a standard of stability superior to that shown in the example cited. By using known techniques where the errors in slip gauges as declared by the National Standardising Authority can be allowed for when measuring secondary sets of slip gauges, it is possible to pass into the working area sets of slip gauges whose errors are declared to an accuracy of five millionths of an inch.

measuring instruments and calibrated setting masters

It is the duty of management to place at the disposal of the workmen from whom they expect to receive accurate work, the most convenient means of production which can be provided and which is economically justifiable. Included in such facilities should be the means whereby the workmen can observe the magnitude of the changes in size which occur as production proceeds and which, in most

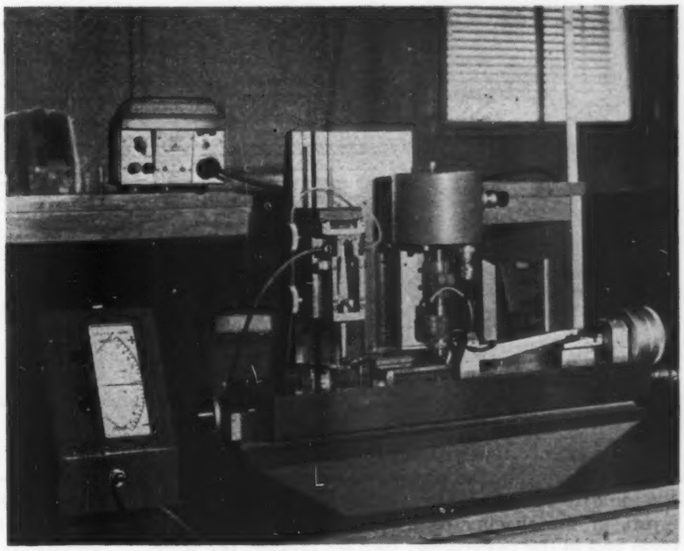


Fig. 30. High precision internal measuring machine.

cases, are inside the work tolerance. The magnification of the measuring instrument which is recommended for a wide range of tolerances is shown in Fig. 26. The standards of accuracy of the measuring instruments should be as follows :—

Type of Error	Maximum Allowable Value expressed as percentage of work tolerance
Repeatability of Reading	± 2%
Accuracy of Scale	± 2%
Rigidity of Comparator	± 2%
Observational Error	± 1%
Error of accepted size of Setting Standard	± 2%
Drift	± 1%

the use of calibrated setting masters

One method for placing an accurate and convenient basis of size at the disposal of the operator is to provide him with a setting master which should be made as near as possible to a target dimension situated midway between the tolerance boundaries or, alternatively, as near as possible to the ideal size of the finished part, if this ideal size is known. When the setting master is finish machined, it should be passed into the standards room for measurement and the issue of a chart of the type shown in Fig. 27.

The drawing in Fig. 27 shows the following three significant dimensions :—

1. The ideal size of the part.
2. The amount by which the setting master differs from the ideal size.
3. The maximum amount by which the size of the part can exceed the ideal size and still be acceptable.
4. The maximum amount by which the part may be smaller than the ideal size and still be acceptable.

With the above data as a basis the measuring instrument selected for the workman to use at the machine can be selected from the chart in Fig. 26. For tolerance IT5 on a nominal diameter of one inch, the magnification should be 5,000. Fig. 28 illustrates the scale of an instrument of this magnification. The zero line on the instrument scale is used to indicate the ideal size and the tolerance markers indicate the maximum deviation in a plus and minus direction which can be tolerated. The dimension minus 0.00005 in. is marked on this diagram to indicate the position on the scale where the pointer should rest when the instrument is measuring the calibrated setting master. For ease of operation and as an aid to rapid and accurate measurement, a back stop should be fitted to the instrument as illustrated in Fig. 29.

manual and automatic positioning devices

The machine illustrated in Fig. 30 is an interesting example of the ease with which it is possible to place a slide in any required position to a very high degree of accuracy over a distance of four inches. The machine incorporates a scale on which 401 lines are engraved at a distance of 0.010 in. apart. The lines are observed by a photo-electric microscope and when one of the lines is one millionth of an inch away from the optical axis of the microscope, the signal from the microscope causes the beam of a sensitive galvanometer to be deflected 0.200 in. on an engraved scale. By the arrangement shown in Fig. 31 the one inch travel of the non-rotating anvil of the micrometer causes the scale to move 0.010 in. which is the distance between the engraved lines. One division on the micrometer drum which represents a movement of the micrometer anvil of 0.0001 in. causes the engraved scale to move one millionth of an inch. The mechanism for moving the scale was

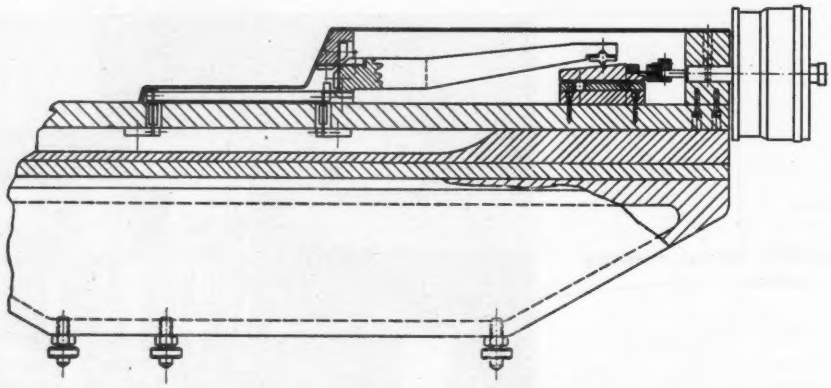


Fig. 31. Arrangement for moving scale on internal measuring machine.

operated twenty times to test the accuracy of repeatability and all the readings were within a band corresponding to less than one millionth of an inch. The errors in the spacing of the lines on the engraved scale and in the mechanism used for moving the scale can be determined and calibration values established by direct interferometry to an accuracy of one millionth of an inch. The complete equipment, therefore, provides the means of moving an air lubricated slide over a distance of four inches to an accuracy of about three millionths of an inch, or two parts in a million, whichever is the greater.

By fitting binary scales to a suitable gear train, which can be arranged to rotate the micrometer drum, it is possible to arrange for the machine to go through any predetermined programme of movements to a high standard of accuracy. In the machine, as designed, the slide will move through a distance which is related to the size of the ring gauge being measured, and the measured size of the gauge can be displayed on a panel or printed out by an electric typewriter. It is possible to develop a two or three dimension co-ordinate measuring machine on this principle.

It is probable that the combination of the photoelectric microscope with a high precision scale will be introduced to an increasing extent in high precision

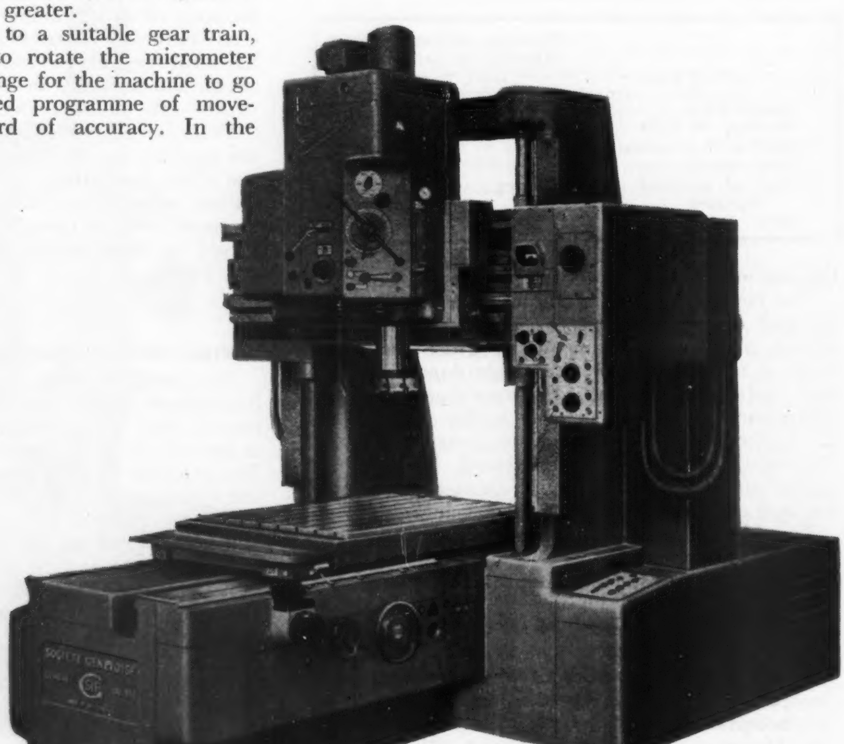


Fig. 32. High precision jig borer incorporating high precision scales and photoelectric microscope for automatic setting.

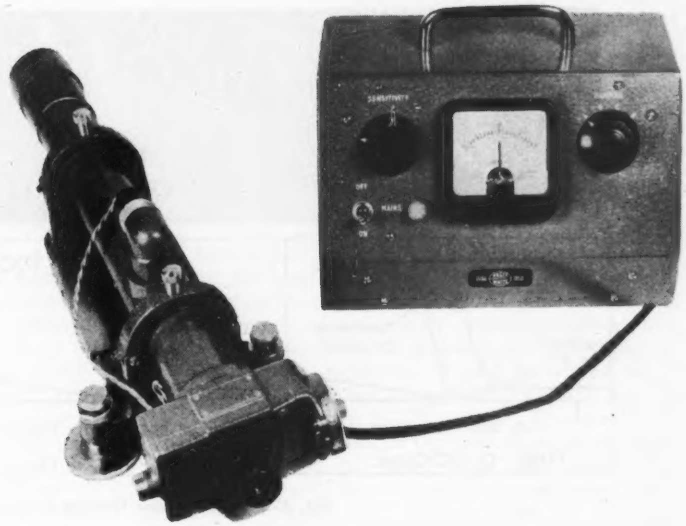


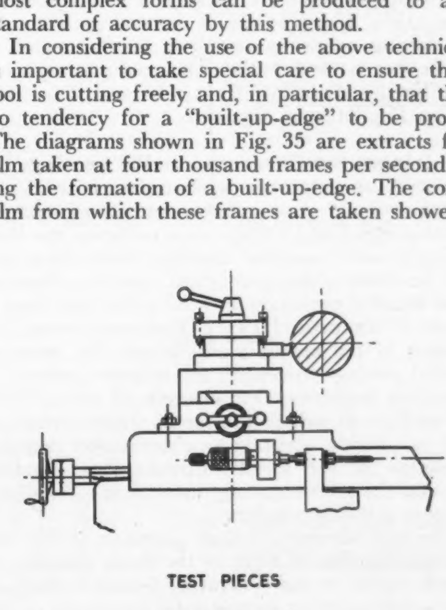
Fig. 33. Autocollimator fitted with photo-electric microscope.

measuring and manufacturing equipment. The manufacturer of a well-known jig borer has introduced this technique on a new range of jig borers, and, as an alternative, has used almost the same equipment for the construction of three dimensional measuring machine, as illustrated in Fig. 32.

The photo-electric microscope previously referred to has been used to good effect, as shown in Fig. 33, by increasing the accuracy of measurement attainable by autocollimator. The error of reading has been reduced to about one quarter of that which is obtainable under carefully controlled conditions, with a good quality optical system.

In addition to the very high precision work referred to in the Paper, there is a real need for the development of techniques which will provide a higher standard of precision in the methods used for positioning the metal cutting tools used in a wide variety of manufacturing operations. From the many machines which could be used to illustrate this technique, the simple centre lathe will provide a satisfactory example. Fig. 34 illustrates an arrangement for measuring to a high degree of accuracy small movements on the cross-slide on a centre lathe. The technique used is to operate the machine in the normal manner until the part is about 0.005 in. above finished size. With a free cutting tool, take a further cut which will reduce the diameter to about 0.002 in. above finished size. Withdraw the main saddle of the machine without disturbing the setting of the cross slide. Measure the part with a high precision calliper gauge which with its associated indicator should give readings accurate to about 0.00001 in. Let it be assumed that such a measurement indicates that a diameter must be reduced by 0.00264 in. to bring the part to finished size. This measurement shows that the radius of the part must be reduced by 0.00132 in. By the arrangement shown in Fig. 34 adjust the micrometer screw until the indicator attached to the measuring unit reads + 0.00132 in. Adjust the slide until the indicator reads zero. Take the final cut at the speed and feed used for the previous cut. The table attached to Fig. 34 shows the departure from standard on seven test pieces which were turned on a high precision centre lathe of standard design using the above technique. This principle can be applied to the finish machining of bores, depths, etc., and most complex forms can be produced to a high standard of accuracy by this method.

In considering the use of the above technique, it is important to take special care to ensure that the tool is cutting freely and, in particular, that there is no tendency for a "built-up-edge" to be produced. The diagrams shown in Fig. 35 are extracts from a film taken at four thousand frames per second showing the formation of a built-up-edge. The complete film from which these frames are taken showed that



TEST PIECES

TARGET SIZE 0·5000"

	A	B	C	D	E	F	G
DEVIATION FROM TARGET SIZE	−·00005" −1·3μ	−·00015" −3·8μ	−·00010" −2·5μ	−·00015" −3·8μ	·00000" 0	−·00005" −1·3μ	−·00007" −1·8μ

Fig. 34. Setting device fitted to standard centre lathe.

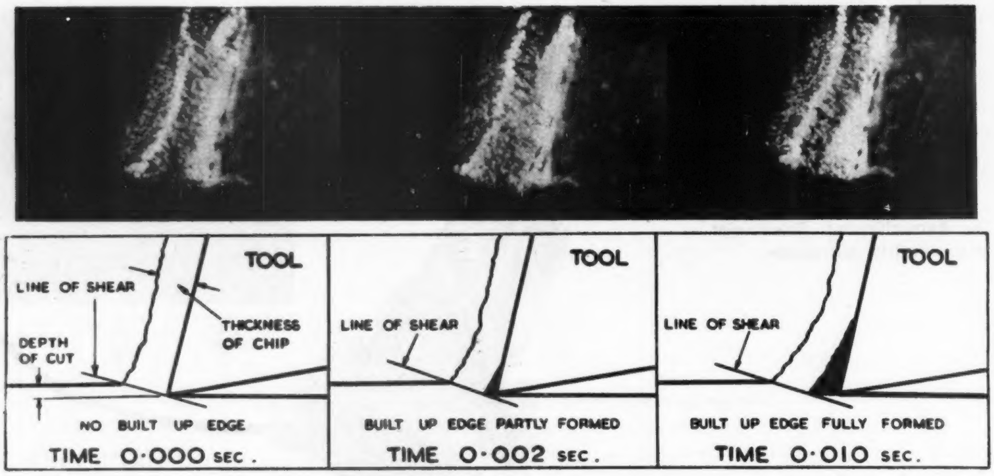


Fig. 35. Built-up edge forming on turning tool.

a built-up-edge was formed on four separate occasions and carried away with the chip during the machining of a test-piece in which the tool travelled a distance of ten inches. In one of the preliminary tests using the above technique, the results were found to be very unsatisfactory. Detailed investigation showed that the cause was the built-up-edge being formed occasionally during the finish machining operation. This was due to the tool used for the finish turning operation having a large amount of side rake but no front rake. The tool was replaced by one having about 20° front rake and the results shown in Fig. 34 were obtained.

moiré fringes for linear and radial gratings

No survey on automatic position devices would be complete without some reference to moiré fringes. The techniques used by firms manufacturing the electronic equipment and the machine tools using this system has been widely publicised, and it is thought that no detailed explanation of the techniques used is necessary in the present Paper. The more recent development in the use of moiré fringes has been to use radial gratings to control the relative position of two rotating members. One example of this is illustrated in Fig. 36, where the moiré fringe technique is used to provide accurate synchronisation between the rotation of the spindle carrying the grinding wheel, and the table carrying the gear in a high precision gear grinding machine.

In the manufacture of high precision gears, one of the main sources of error in the finish grinding of the tooth profile by the generating process is the lack of true synchronisation between the movement of the grinding wheel C, Fig. 36, and the gear D. The present arrangement for ensuring synchronisation between these two elements is to use a gear train between the spindle 3 carrying the grinding wheel, and the shaft F carrying the single start worm through which the table G carrying the gear D is driven. By using an electronic control it is possible to arrange for the slave motor H connected to the single start worm to be driven at a speed which causes the number of radial gratings passing the sensing head associated with disc B to be the same as the number of radial gratings passing the sensing head associated with disc A.

In considering the grinding of gears of very high precision, it is recognised that the arrangement described may include some error, due to the inaccuracy of the worm and wormwheel combination. This can be reduced to a very small value by measuring to a high degree of accuracy the magnitude of the error in the worm and wormwheel combination and arranging for the radius to the surface of a disc type cam, J, which rotates at the same speed as the machine table G, to change in sympathy with the known errors of the worm and wormwheel combination. This can then be arranged to cause the sensing head K to move through an angle which is in sympathy with the measured error and this causes disc B, and with it the slave motor, to move at a speed which ensures the table G rotating in true synchronisation with the grinding wheel C in spite of the errors in the worm and wormwheel combination.

One further requirement in a machine of this type is that the grinding wheel, C, should be brought into accurate angular location with the gear being ground. This adjustment should be carried out to a high degree of accuracy to ensure that a uniform amount is ground from the two flanks of the gear tooth. A single contact cam L on the shaft carrying the grinding wheel C impulses a powerful stroboscope lighting unit which provides a flash of short duration for each revolution of the grinding wheel. This arrangement has the effect of causing the grinding wheel and the gear being ground to appear stationary. By observing through a closed circuit television unit the profile of the grinding wheel in relation to the gear being ground, and by manually adjusting the sensing head

K, it is possible to bring the grinding wheel into mesh with the gear while both are rotating at normal grinding speed.

The replacing of a gear box by an electronic unit, as described in the above example, emphasises the need for engineers of the future to be trained in the basic sciences associated with both mechanical and electrical engineering.

final recommendations

The picture painted by the present Paper is of a situation where by the application of known scientific knowledge to certain manufacturing problems it would be possible to obtain a substantial improvement in efficiency. This should not be taken as an indication that it is only necessary to purchase a comprehensive range of measuring instruments and control equipment in order to obtain this improvement. The real need is not for equipment, but for men who can operate so near to the manufacturing unit that they can appreciate all its practical implications and, in addition, have a good understanding of the basic sciences underlying the technology of engineering manufacture and the philosophy of measurement and automatic control.

The engineering industry requires well trained engineers who have the ability to apply this known scientific knowledge to the needs of industry. It is unfortunate that the management of many companies and the production engineers who are grappling with the day-to-day problems of industry and who, in many cases, are said to have "come up the hard way", do not appreciate the immense benefits which can be obtained by a suitable combination of applied science and practical experience.

One final word of warning. At the end of the present decade, machine tools, control equipment and other technical devices will have been developed to such a degree of perfection that there will be available a mechanism which is suitable for doing most of the things which it is really necessary for us to do to ensure that the people of this and many lands enjoy a high standard of living. The one outstanding requirement will be the need to improve man's behaviour towards his neighbour. This is a problem which is worthy of detailed study on a national and

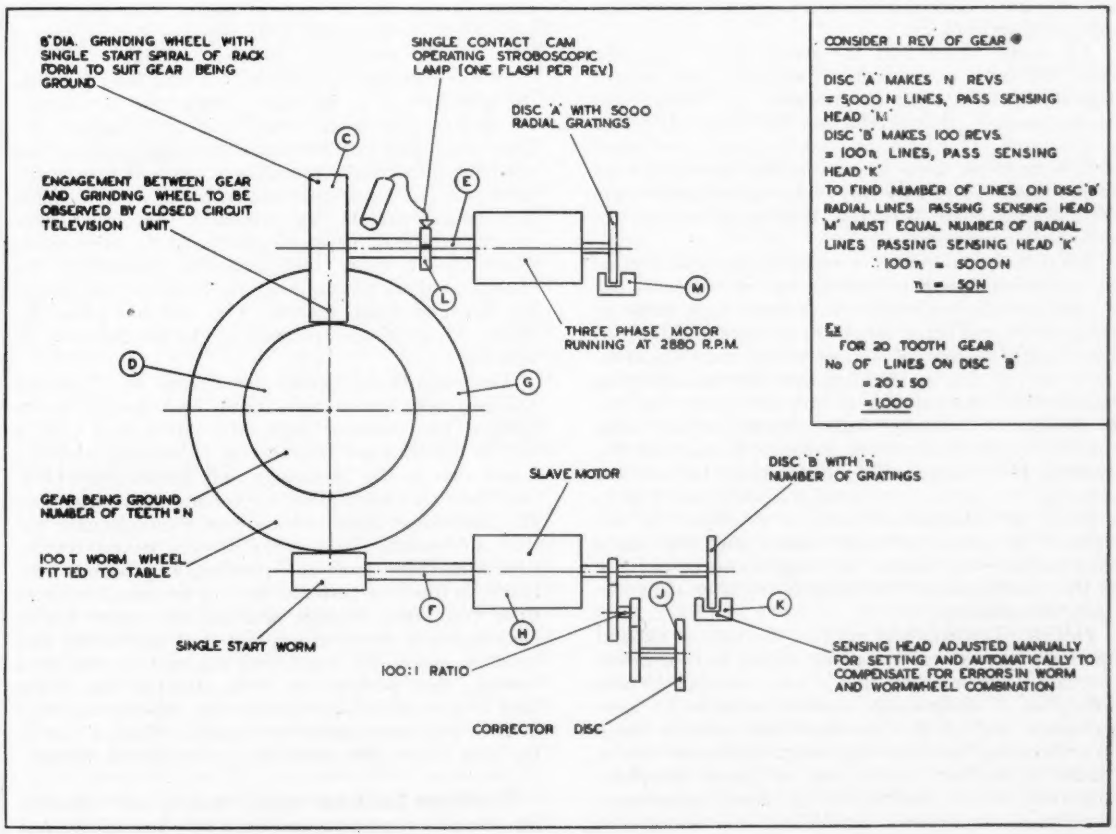


Fig. 36. Electronic drive for table of high precision gear grinder.

think that by automation the machine operator becomes a person of little or no importance who merely loads the machine, presses buttons, and pulls levers. As the technique of engineering manufacture becomes more complex and the capital value of the plant placed at the disposal of the operator becomes greater, there is created a demand for a new type of craftsman who by his knowledge, his intelligence and his interest in his job can keep the automatic unit operating at a high standard of efficiency.

As I see it the challenge of the future will not be, "Can we produce machines which will do what we want?". This is assured. The challenge for the management of the future is, "Can we provide the environment which is necessary to make the most complex of all mechanisms, man himself, operate to the exceptionally high standards of efficiency of which he is capable?". I believe this to be possible.

DISCUSSION

Chairman: Sir WALTER PUCKEY, M.I.Prod.E., Past President.

Mr. K. J. Hume (*Reader in Engineering Production, Loughborough College of Technology*) said that they had been both enlightened and enlivened by what Professor Loxham had said. Unpredictable as he might be on some occasions, one could always predict that he would give an address which contained a great deal of information, common sense and advanced technology.

All would agree that the trend for a very long time had been to concentrate scientific and technological resources upon the research and design side of the product; that production had been left rather in the lurch. This must inevitably change, and more and more effort must go into developing the science of production. In many ways this was infinitely more complicated than was the traditional science of ordinary engineering.

What had to be done in industry was also needed in education. Much rethinking was in evidence, but it needed to be undertaken at a faster rate. Some of the subjects still being taught at colleges and Universities had to be looked at quite coldly and dispassionately with a view to deciding whether they were as fundamental and valuable as they once were. He had in mind, for instance, heat engines, which were studied by the majority of students throughout the country. How many really needed this? He was not pleading for purely vocational training—one had to consider the educational value of a subject. It was claimed, in defence of heat engines, that this was a basic engineering subject, but was it any more basic to the production or mechanical engineer than the study of metrology?

Professor Loxham had not had the time to expand upon the question of geometric shape, but engineers generally were realising that a large number of past difficulties of dimensional control, accurate fit, performance, and all the functions that went to make up engineering had been due not to inaccurate size or control of size but to complete, or almost complete, ignorance of the significance of shape; roundness, straightness, squareness, parallelism and so on—all the things that there were now instruments to measure. He was thinking particularly of roundness.

One or two experiments that Mr. Hume had undertaken recently to demonstrate the accuracy of methods of measuring bores had, he felt, been rather significant. Everyone was familiar now with the idea of lobed diameters and the fact that one could not detect this with straightforward diameter measurement. It was just as true, of course, that one could not detect ovality with 120° three-point gauging, a very popular method of internal gauging.

In the experiments some bushes had been put into the grinder—in a three-jaw chuck and a two-jaw chuck to grind them lobed and oval respectively. They had also checked some in which errors had not been deliberately introduced and had found that there was still significant lobing. More work, possibly as a student project, was proposed. It would further investigate the dimensional errors and the form errors which could, quite innocently, be introduced by various methods of clamping, for instance, the clamping down of rough castings. One did not know the extent to which components might be distorted in this way.

Two significant points mentioned by Professor Loxham were concerned with air bearings and moiré fringes. The previous week Mr. Hume had paid a visit to the National Engineering Laboratory and had found that in the Metrology and Mechanisms Division these two matters were receiving great attention. His impression after visiting that establishment was that air bearings and moiré fringes would revolutionise machine tools and production processes generally, as much or perhaps more in the next few years than computer controls and all the more highly electronic and involved techniques of which they had heard so much. He mentioned this only by way of a warning that perhaps too little attention was being paid to the significance of these two aspects, and that a great deal more would be heard of them, if not in the near future then certainly in the distant future.

Professor Loxham replied that, as one expected, Mr. Hume's comments had been very helpful. At one period he had become quite excited about the folly of heat engines being taught to an advanced level in

technical courses designed primarily for production engineers. His present feeling was that, while the position was not satisfactory, it was improving. In reply to Mr. Hume he would like to say that metrology was absolutely essential for the production engineer. Richard Hazleton, the first Secretary of the Institution, had asked him, thirty years before, what should be done to make production engineering a science. His answer was the same then as it would be now: "If you want to make production engineering into a science, you must begin by taking measurements and then you must analyse them". Metrology was the science of measurement. One could do almost nothing without it. He would describe it as the starting point. It should most certainly be in the curriculum.

His present thinking was that heat engines should be replaced by some special kind of electrical engineering. Heat engines as a subject was important when the steam engine was the prime mover. The electric motor was now the means used for providing motive power and it was possible to obtain a Higher National Certificate and not understand the principles under which a motor operated. Production engineers often grappled with problems without always appreciating the potentialities of the various forms of electrical drive that were available.

Turning now to the question of clamping, he would mention that on one occasion he had been concerned with the control size on parts milled with duplex milling heads on a milling machine with a large rotary table, in which ten jigs were mounted. It had been reluctantly agreed that the tolerances on three dimensions should be extended. He had been brought in at the eleventh hour to try and avoid this. Briefly, measurement had shown that four of the jigs only were producing faulty parts and the six other jigs were producing good parts. When one had a large number of finish machined parts in a box and it was not possible to relate them to their own particular jigs, one had no clue about the cause of the error. Further examination had revealed that distortion as a result of clamping was the sole cause and the tolerance was to be extended in respect of all pieces, quite unnecessarily. The production engineer's job was to analyse that kind of problem and discover for himself what he was capable of doing.

Air bearings and moiré fringes had an exciting future. In his view, the machine tool industry could make machines for grinding on which the slide would move along a straight line to a very high degree of accuracy. In a recent grinding experiment they had mounted vertically an optical flat plate about 7 in. in diameter on the table of a cylindrical grinding machine. An air jet fastened to the wheel head had been brought into close proximity to the plate so that, when the slide reciprocated, the gap between the jet and the plate provided a means of investigating the movement of the table. One could adjust the plate until the gap became reasonably uniform. The air jet was connected to a recorder on which a trace was drawn showing the variation in the air gap between the jet and the plate, which was a measure of the extent to which the table moved along a straight line. At a magnification of 15,000, it was possible to record results accurately to ten millionths of an inch, and as a result of this work he had less confidence in vees and flats than hitherto.

One could not grind parallel when the error in the movement of the work table was 0.00015 in. One could grind more parallel even under these conditions if one let the machine run for ten minutes so that, by random cutting, it would continue to cut during a long spark out period, but this was not good production engineering. He was confident from tests he had carried out that an air bearing on a slide of suitable design would move straight to within ten millionths of an inch. This was because the air film could be made to average out the irregularities of the mating surfaces and errors in the slides could be divided by a factor of ten. This would help one to make very accurate slides.

Mr. L. Webster (*Production Manager* (*Engineering*), *Distington Eng. Co. Ltd.*) wondered whether Professor Loxham, in speaking of diminishing returns, had taken into account the depreciation of the pound over the years.

They had been told of a measuring micrometer attached to a lathe which allowed one to take off precisely $4\frac{1}{2}/10{,}000$ and not $4/10{,}000$. He had yet to find the lathe which would enable one to differentiate to that extent.

Were any developments taking place in metrology that could be applied in the heavy engineering industry, as opposed to the light?

Professor Loxham replied that he had been careful not to adopt the dangerous course of citing figures in the graph showing the low of diminishing returns. He would prefer to give an example. The ordinary three-phase electric motor of about 5 h.p. would drive a machine tool with about 95% efficiency when examined as a study in thermal dynamics. If that type of motor was ever made into a device which was better value for the work it had to do, the production engineer would have a large part in its development. It may be made cheaper or better because of some new material or manufacturing process. The electrical engineer had done his work so well that there was little more for him to do on this particular type of machine.

Given the time, Professor Loxham would like to say more about the new concept of product design in which the designer co-operated with the production engineer to effect improvements. One had to find out what the designer wanted and the production engineer should then seek some liberty to modify the design so that the end result would be what was desired.

He had been careful to say, in relation to the lathe, that one could move the cross-slide to an accuracy of ten millionths of an inch if this was required. This statement was true and would be demonstrated during one of the laboratory periods of the Symposium. To obtain this standard of accuracy on the work was a different matter. When they had used this technique on the machining of test pieces to an accuracy

of 0.0001 in. they had been unable to hit the target. Upon investigation it had been found that a small built-up edge was forming on the tool, which had been made with a lot of side rake but no front rake. When the tool had been changed for one with 20° front rake, the results shown in Fig 34 in the Paper were obtained. Therefore, the geometric shape of the tool was of great importance in order to ensure a good, clean cutting action.

The tolerance set as the target figure in the test was ± 0.0001 in. The errors of parallelism and roundness on the lathe used were 0.00005 in. when using a suitable tool.

On the question of heavy engineering, Professor Loxham was Chairman of the B.S. Committee on Limits and Fits, and he had on his desk at the moment Part III of B.S. 196, which was concerned with dimensions up to 200 in. and was concerned for the purpose with the fixing of tolerances for sizes from 20 in. to 200 in. The National Physical Laboratory had carried out a survey to find the standard of accuracy to which people in the heavy industries could measure large dimensions. The results had indicated that there was need for investigation and improvement. For instance, the internal bore of a large alternator might be 15 ft. in diameter, but the air gap between the rotor and the stator should, for maximum efficiency, be made as small as possible. The first time that the rotor and stator went together might be on the test bed or in South Africa, when they were assembled.

The matter should be examined carefully, and he felt that those attending the Symposium could play a big part in an investigation which was to be set up for the purpose of improving the present very unsatisfactory position. The scientific knowledge available could and should be applied immediately, because it would produce substantial benefits at very little cost.

Mr. L. J. Blache (*Elliot Bros.* (*London*) *Ltd.*) said that Professor Loxham had described some of the hyper-efficient control systems for use with simple forms. What development work was going on in his laboratories for carrying out the same tasks with long, slender components of the kind one encountered in the manufacture of gyroscopes? How would he tackle the problem of size where the presence of a measuring probe would cause objectionable deflection to the component part? Could form be measured by variation in position of the workpiece, for example, at 180° to that at which the raw material was removed; and, generally, what philosophical approach was he making to this?

He had found that one of the basic problems was workpiece methods, so far as holding was concerned. It was extremely critical. Whereas, in the past, many precise components had been made by way of workshop reports, one had now to draw thumbnail sketches giving details and design special fixtures which would deform the workpiece as little as possible, for example, by clamping it along a certain axis. Did Professor Loxham feel that stress-free methods were being exploited as much as possible? He had in mind such methods as electrolytic grinding and spark eroding.

Professor Loxham replied that, at the risk of being thought something of a salesman for the type of training provided at Cranfield, he would say that the average person with a Higher National Certificate or, indeed, a University degree, was not fully trained to undertake the big and difficult task to which the questioner had referred. One found, for instance, that the students coming to the College with a Higher National Certificate in Production Engineering did not know enough about fluid mechanics, electrical engineering, electronics, materials and mathematics.

The need of the man from the University might be different. He would have studied physics to a high level and might have a knowledge of electrical engineering and electronics, but his production engineering was not sufficient. Although the College had been set up primarily to meet the needs of the aircraft industry, it was now able to assist the machine tool and other industries wishing to apply analytical investigation to their methods of production. The best way that he knew for companies to undertake research of the type discussed was for them to sponsor a student with the necessary qualifications and ability, so that he could attend the one-year course on Precision Engineering now being provided. In addition to filling certain gaps in the student's knowledge, it would be possible for the student to use a problem of the type suggested as a thesis study on which serious experimental work could be carried out.

Providing the necessary support to objects while they were being machined was, in some cases, extremely difficult, especially with thin-walled pieces of the type used in gyroscopes.

It was usually helpful with problems of this type to endeavour to state the conditions necessary for ensuring the standard of accuracy required. In this case under review, it would be:

1. work holding spindle must rotate about a fixed axis and have no axial movement;
2. the work must be held without imposing distortion;
3. for the production of cylindrical parts, the tool must move along straight lines parallel to or at some predetermined angle to the axis about which the work is rotating;
4. the cutting tool or other device must remove the surplus material without imposing objectionable forces on the work;
5. the measuring equipment used to determine size must not apply forces of sufficient magnitude to distort the part to an objectionable degree.

It is by endeavouring to satisfy requirements tabulated in this way that a method can be devised which can be tried experimentally. From the results obtained more refined methods can be used and usually a satisfactory method of manufacture can be established.

The suggestion of removing material by electrolytic methods was certainly worthy of careful investigation.

This type of investigation was one of the methods used in the College machine tool laboratory. The benefit of a firm sending a student to work on such a project was that when the period of study was completed, the firm obtained a report on a subject in which they were interested and, in addition, its author.

Professor Loxham would be pleased to communicate with the questioner or anyone who thought he had a problem which could be solved along the lines he had suggested.

Mr. F. Roberts (*U.K.A.E.A.*) thought that, after the skirmishing of the previous evening, Professor Loxham might have prefaced his Paper by saying "Let battle commence". He had got down to the sort of thing that one felt was proper to the Symposium.

The subjects in respect of which the curves had been drawn had, he felt, been well chosen to show what was wanted. Perhaps the curves, which were asymptotic to infinity, might be developed into a second series which were asymptotic to some maximum.

He hoped that the suggestion that design should be stabilised would not apply to machine tools, which had been stabilised for far too long! Certainly, it ought not to come before they had been given the benefit of the improvements which were so readily available in the laboratory, and in the development shops but not on the machine tool.

He could not share Professor Loxham's hope that conditions would improve markedly in the next ten years. People who had continued in the same old way for 20 years were not likely to change in the next ten. All one could hope for was the introduction of new blood in the way Professor Loxham had suggested.

In regard to the actual task of making things accurately, most of the work had been concentrated on grinding. The process was one where the operator removed a very small amount per unit of feed in relation to the tolerance given. The principle might be obvious but had perhaps not been stated sufficiently. It was the essential difference between the work of grinding and the work of the centre lathe.

The other thing he would mention about tight tolerances was the difficulty they had experienced as a result of temperature variation. It was not difficult to control temperature during manufacture, but when specifying tolerances it should be remembered that one could not control the temperatures of usage. In normal circumstances, where temperatures varied differential expansion between two components would cause trouble and the carefully chosen tolerances would not be met.

Could more information be given on the production of complex forms? No doubt lack of time had prevented Professor Loxham from saying more on this, and on the accurate working of a centre lathe. One difficulty was that although one could move the tool the necessary amount, the head did not stay where it ought to. Consequently, neither did the workpiece, thus giving rise to error. They had had some experience of the distortion of castings, and here stress-less methods did not always give the desired result. The stress was already present, in the component and when one removed the metal it made itself felt. What means were there of overcoming this problem?

He had been interested to hear of the experiments in which an optical flat had been put on the bed of a grinder. Recently he had visited a machine tool firm in America where exactly this had been done. They had set their table by using an optical flat in this way, and had got a very accurate movement. Whether it was necessary did not matter. The point was that they had taken the trouble to do it in order to get a good result.

The suggestion that firms with problems should send students to the college was a very good one but, having come to the college and found an answer, how was one to put it into effect? Many of them had the technical answers to their problems now, but could not get the co-operation of the firms in solving them. The machine tool industry was selling all it could make and in such circumstances one was not likely to get them to accept the awkward or difficult job.

Professor Loxham said that he had been trying to make the point that the rapid improvements that had been taking place should now begin to take place in production engineering, and, in particular, in the machine tool industry. At least part of the machine tool industry was reacting better than hitherto.

Rolls-Royce had a difficult machine problem in connection with turbine discs and were sending a student to the College to study it. Alfred Herbert's were loaning machines worth £5,300.

Offers had come from the machine tool industry to the value of about £50,000 for the loan of machine tools to the College. Some of the machines would be seen in the laboratory. The College had been invited to carry out experiments with the object of establishing new and improved standards of performance. He was quite hopeful, therefore, concerning the present attitude of the machine tool industry, compared with that of ten or fifteen years ago.

He was interested in the centre lathe. Indeed, one important investigation being carried out by the College was on a centre lathe. Discs worth from £100 to £400 each when finished were required, with about 12 dimensions on each disc to small tolerances, and the scrapping of parts of this value was a serious matter. He had taken part in a very interesting investigation conducted by Alexander Stephens on the Clyde, who were faced with a very similar problem. The firm had agreed to make four high-speed steam turbines to the design of another company. The forging for the turbine rotor was valued at about £2,000. It had been gouged out so that there were 15 flanges, and on the periphery of the flanges a complicated profile was formed. On each profile there were 10 dimensions with a tolerance of $\pm$ 0.00025 in.

The poor operator, upon seeing the drawing which included finer tolerances than he had seen before, said, "This is impossible and I am not going to try to work to these tolerances". A device was made which, by measurement, showed clearly how much

this man had to take off, using the principle illustrated in Fig. 34.

He would like to quote what Mr. Hansard, the Production Manager of the firm, had said about this experiment. It was as follows: "Finally, one observation is worthy of mention. It had been anticipated that the new technique would meet with some resistance from the shop floor. After all, old methods die hard in the heavy industries. For this reason, the way was prepared by inviting the co-operation of the machinists, the inspector and foreman, and keeping them fully informed as to the proposed method of attack and the progress of the equipment from the design stage onward. Despite initial cynicism, there was a wealth of sincere and intelligent co-operation. Towards the end, the machinists and the inspector became the most earnest protagonists for continuous measurement during machining". The man who had threatened to leave had become quite interested because he could see that the task was attainable and indeed a very interesting problem. In such circumstances, most people responded very well indeed.

The technique employed was a development from the simple micrometer that he had mentioned. One used normal methods to make the part within about .005 of the size, set an indicator to read + .005, move the tool .003, take a further cut and the indicator shows the part to be + .002. This gave one the necessary confidence and the final cut was taken. Mr. Hansard said that on the four rotors, each with 15 flanges and 10 dimensions on the periphery of each flange, all the dimensions were within tolerance. The turner had told him that they were the best turbine discs they had ever made, and had really been proud of them.

In some cases, the man at the machine was given an almost impossible task. One of his worries was that with more and more people going to the universities, there would be a tendency to feel that the graduate was a superior person who did not require any technical assistance from the man operating the machine. The latter had usually much more knowledge about the actual job and any policy of telling the people on the factory floor that they must not think, but simply do as they are told, could only lead to trouble. It was not too much to say that, given the necessary scientific aid, the operator could become quite fascinated with his work.

Mr. I. S. Morton (*Snr. Technical Adviser, Shell International Petroleum Co.*) said that, in his experiments with the centre lathe, Professor Loxham had changed the tool shape until the tendency towards a built-up edge was removed. Had he tried eliminating build-up by changing the cutting fluid? One could devise a cutting fluid so highly active that it would react with the material of tool and chip to give the lubricating film desired. If it were of sufficient activity one could virtually eliminate the built-up edge. However, a choice had to be made between the clean, accurate cut with good surface finish, and the protection of the tool. Corrosive wear could take place, and the protection of the built-up edge, which many thought prolonged the life of the tool, would be lost.

In some cases one had to obtain a certain standard of accuracy to make the job worth doing, and then tool life had to take second place. He had seen experiments with gas turbine materials which supported this contention.

Professor Loxham replied that the investigation of plastic deformation of material was very important. By using a stroboscopic lighting unit, a film had been produced at a speed of 4,000 frames per second and each frame had an exposure time of only 2 millionths of a second. This had produced a very sharp image for each frame and if one examined the frames individually one could study the nature of the plastic deformation which occurred during the formation of the chip. One could also measure the force and analyse it. It was then possible to use a different approach angle, or, as had been suggested, use lubricants to achieve the desired result. The plastic flow of the material also changed with speed. One could see what was happening very much better than by normal observation and, as a result, was much more likely to develop the right cutting tool geometry and the best lubricant.

Once this had been done, it was possible to experiment with the depth of cut which would give the best finish. They hoped to take photographs at the rate of 8,000 frames/sec. and increase the cutting speed to about 500 ft./min. instead of the maximum of 100 ft./min. obtained on the planing machine, on which all films so far taken had been made. By this means it was hoped to ascertain, for a particular material, a cutting tool geometry, a depth of cut and a speed of cutting—also lubricant, which he agreed was tremendously important.

Britain had such limited resources that they should get together and arrange that each centre, such as Manchester or Birmingham, concentrated on each aspect of the problem. His efforts in that direction seemed to be making progress.

As a result of experiments made at the College, they would see a milling cutter removing metal faster than he, at any rate, had seen it removed elsewhere. The course to adopt became almost obvious when one was able to see what was happening.

He agreed with Mr. Morton that the two aspects —tool geometry and fluid change—were alternative courses open. It was a question of seeking the optimum in both cases.

Mr. J. W. East (*Assistant Manager, War Office R.O.F.*) asked whether they could be given any indication when the tool manufacturers, especially the grinding wheel manufacturers, were going to catch up with the advances made in metrology, including the greater speeds now possible. Were they likely to lag behind the machine tool designers, who were at least trying to catch up? Apart from the manufacturers' handouts he could find no practical information—certainly not of a precise nature—from the grinding wheel people concerning what they were doing in this direction.

Professor Loxham had referred to roughing, finishing and spark-out. In his chart he had shown a mysterious phenomenon—the wheel apparently becoming larger and smaller in turn. He had put it down to first the loading, and then the exposure, of the cutting edge. This was perhaps a more real assumption than even his particular example had shown, in that spark-out sometimes did not happen at all in the sense of changing the dimension of the piece.

Professor Loxham agreed that the grinding wheel situation was especially interesting, and warranted scientific investigation. Recently he had been told that one could not specify, in any precise way, that such and such a wheel was the best for a particular job. The reason given was that one had simply to try things out and see whether the user liked them, making alterations as needed. He was aware of a circumstance where a certain machine was in use on both day and night shifts. When the night shift grinding operator came on he took off the grinding wheel used by the man operating the machine during the day, because he was convinced his own selection was better. Members could see at the College a grinding operation in which there were no sparks at all. The table was moving at 40 in./min. while they were grinding 90 ton stainless steel.

Under a microscope the chips appeared to be of the same form as chips taken by a turning tool. The College was being loaned a Thompson grinder to enable this phenomenon to be investigated further. The Carborundum Company had promised to co-operate in this experiment by making wheels available as required. The purpose was to develop a technique for removing metal by a grinding wheel without setting up the heavy and highly objectionable residual stresses normally present in a ground surface. In gear grinding and the grinding of the tracks of ball and roller bearings, failures had occurred as a result of residual stresses set up in the surface. In some cases, these cracks were only .001 in. deep. In others they were deeper. Sometimes, when the crack had not developed, the material was in a state of tension and further loading led to failure by fatigue.

The College was taking the lack of scientific knowledge on grinding very seriously and hoped, within a year or two, to have produced some type of order out of chaos. He would like to think of a grinding wheel as a milling cutter with a large negative rake and not a device which removes the material in such an inefficient manner that the swarf becomes red hot. Research at the College had resulted in the development of a grinding technique in which no sparks were produced when grinding steel and very low residual stress in the surface of the ground material compared to normal practice. Another example was a milling cutter which had been developed in the department for the machining of high tensile steel in the fully heat-treated condition. Preliminary tests indicated that the tool life appeared to be about five times that obtained from a normal cutter.

Mr. D. Ridgeway (*Development Engineer, Gear Grinding Co. Ltd.*) said that he had done a considerable amount of work with a grinding wheel operating at a traverse rate of approximately 12 in./min. and removing .007 in. or .008 in. It appeared that, between 6 and 12 in./min. one did not damage the material, metallurgically, as much as at the normal rate of 40/ft.min. The only difficulty had been an increase in wheel deflection and component deflection. When grinding material on which there was a tendency to produce grinding cracks, such as EN 354, there was great benefit in using a table travel speed of 6 to 10 in. per minute instead of the more normal table speed of 40 ft. per min.

Professor Loxham expressed interest in Mr. Ridgeway's findings: the College had not used the slow rates of table speed mentioned but had made the grinding wheel bearing very rigid, and by having a very free cutting wheel with an open structure into which the chips could pass during the cutting process a clearer cutting action was produced. Wheel vibration had been reduced to a maximum amplitude of 0.00002 in. and this reduced substantially the rate of wheel wear and, in addition, maintained a very free cutting action. They had discovered that the downward movement of a vibrating wheel imposed very heavy loads of short duration between the grinding wheel and the work. This caused rapid breakdown of the grinding wheel and heavy residual stresses in the ground material. He would like to co-operate with Mr. Ridgeway in the further development of this technique.

Mr. J. P. Mills (*Machine Tool Designer, H. Hobson Ltd.*) felt that there was a gap between the measuring side, in automatic sizing, and the design of the actual machine tool which had to apply the forces required to correct the errors indicated by the measuring system. Did Professor Loxham believe that the ultimate machine would be designed as an integrated whole, incorporating the measuring apparatus with all the other mechanisms required to operate the machine?

In this connection, two examples came to mind. They had been in use in the ball bearing industry for a long time and were taken for granted by operators. He referred to the Heald Gauge-Matic internal grinding machine and the Landis Raceway Grinder. In both these the sizing equipment was built as part of the machine. In the Landis it was a diamond on an arm, which was pivoted in a fixed position relative to the headstock. The Gauge-Matic machine used a gauge bar going into the bore of the workpiece. When one got down to very fine limits, in cases where the deflection or movement of the spindle took place, would it not be possible to measure the size of the workpiece relative to the movement of the spindle? It would mean using two measuring devices, one on the workhead spindle and the other on the workpiece, thus eliminating the error due to deflection in bearings.

He had recently experimented with air bearings. Though lacking research facilities, he had gone so far as to put hydrostatic pads on a big cast iron block, using a Class B surface table for support. He had employed a restrictor on the inlet side to give automatic compensation for load variation, and wondered whether Professor Loxham was using the same system with his air bearings fitted to a machine slide?

Professor Loxham said that one of the most profitable lines for applied research was for the machine tool manufacturer, the instrument-making firms producing control equipment, and for the users of machine tools to co-operate. By the application of known techniques in a scheme of whole-hearted co-operation, a new range of machine tools could be made available in as short a time as three years. He agreed that the best place to apply the philosophy of measuring was when the machine tool was at the drawing board stage. The improvements which could be obtained would be so great that slides with new types of bearings would be necessary, but the design of these was known. Professor Loxham confirmed that the design of the airbearing for a slide was substantially the same as Mr. Mills had described. The restrictor was an essential part of the design and the main difference was that for air bearings a small recess should be provided after the restrictor, while for hydrostatic bearings it was better to use a much larger recess. Typical dimensions were restrictor 0.020 in. dia. hole recess 0.7 in. x 0.7 in. x 0.030 in. deep for oil, while for air the recess should be about 0.100 in. diameter 0.010 in. deep. Typical pressures were: oil, 300 lb. per square inch and air, 100 lb. per square inch; but he had used air on an experimental rig at 4,000 lb./per square inch with very satisfactory results.

The Chairman said that he would resist the temptation to sum up because he recalled an occasion when another Chairman had prepared his summing up notes before a meeting and had left them in his office, only to have them fall into the hands of his new secretary. She, believing such bad writing could only belong to a doctor's prescription, had sent them off to the chemist, receiving back a bottle of eyewash!

Everyone present had been interested in the great amount of technical information that had been passed backwards and forwards, and as a production engineer he had been fascinated by it. It was a pity that Professor Loxham had not dealt, to the extent he no doubt had intended, with the message that he had really wanted to put across to his audience.

He would quote only one paragraph: "The real need is not for equipment but for men who can operate so near to the manufacturing unit that they can appreciate all its problems and, in addition, have a good understanding of the basic sciences and technology of engineering manufacture and the philosophy of measurement and automatic control." If The Institution of Production Engineers could develop more men with that combination of virtues and philosophy it would become that much greater. They were very fortunate in having, in Professor Loxham, such a man. On behalf of all present, he would say how grateful they were for the care he had taken in preparing his Paper and for the courtesy which he, as one of the senior members of the staff, was showing them, including the demonstrations which had been arranged during the Symposium.

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APPRECIATING THE NEED FOR CONTROL OF QUALITY

by H. W. MANDER, M.I.Prod.E.

Chairman of the Institution's Sub-Committee on Control of Quality

THE complex nature of modern industry has inevitably resulted in the establishment of a great number of ancillary activities which are added to the original fundamental act of production, be it by manual labour alone, with machine assistance, or purely mechanical.

Any addition to these ancillary activities which will cost money, but which cannot be shown before adoption as certain to recover more than its cost, does not arouse great enthusiasm in those responsible for seeing that a production unit achieves the prime purpose of making a profit.

The question, therefore, which will generally require to be answered before facilities are provided to institute modern methods of Control of Quality, is: "What will it cost and what will it save?". This is a reasonable question which must be answered. It is not, however, an easy one and it is very important that as much as possible is discovered of the methods which can be used to establish facts on which the reply can be based.

Mr. F. Nixon, in his E.O.Q.C. Presidential Paper which was published in "The Production Engineer" last month, states that generally direct production operatives produce between £100 and £300 of spoiled work per annum. Most executives in charge of production know, or can easily work out, the average in their own factory.

They will also know, of course, that action is being taken, either intensive or cursory, to improve matters. Very often, however, this is only spasmodic action following a customer complaint, or is sparked off by isolated cases of high cost in scrap or rectification.

At this stage, however, we are considering the very usual situation where there is a strong company opinion that general quality could be radically improved and money saved, but no one is very clear how to set about it. Also, of course, in such conditions there does not usually exist someone with a lot of spare time who is qualified to help in any way.

The interested executive, therefore, has the job of convincing those responsible for expenditure control that time and, therefore, money, spent on improving the Control of Quality is likely to be profitable. Even when an enlightened directorate, implementing the "act of faith" mentioned by Mr. F. Nixon, authorises and initiates action in the belief that it must give results, proof of results is extremely desirable (and will probably be demanded) after a period of operation. Therefore, a "line up" of the items which will enable a "Quality Control Effectiveness" balance sheet to be produced is a real necessity.

the decisive position

In the creation of useable goods there is always a position, i.e., at the finish of the act of manufacture, which is decisive so far as any real Control of Quality is concerned. After the completion of this act there are only three alternatives so far as defective goods are concerned:

(*a*) to throw away as scrap;
(*b*) to rectify (if possible and economic); or
(*c*) to accept, on a concession basis, a lower standard.

None of these has anything to do with the Control of Quality except as information on some action which may be taken in the future on other goods prior to or during *their* making.

The costs, however, of these "failure" actions are very important when analysing the effectiveness of the Control of Quality—this is the gold mine—and it is by showing the reduction of such costs that the effectiveness of expenditure on the Control of Quality, which is to be prior to or during the act of manufacture, can be measured.

Firstly, one must find out what information exists and in most companies there will be some. Usually the easiest to find are "failure" costs, i.e., scrap and rectifications. It should be ascertained that the labour costs are defined as either "actual"—that is, without overheads added—or "total", including overheads. To these costs, if possible, should be added actual or estimated costs of customer placation. There will be some, and the figure will be surprising.

The next step is to review the present inspection activities. Divide the inspectors into:

(*a*) those who are helping to control quality at the point of production, i.e., Patrol Inspectors;

(*b*) those who are engaged in purely "sorting" inspection; and it should not be forgotten that inspectors checking goods from outside must be included.

Calculate the cost of section (*b*) and again make sure whether costs are actual or total. Also, any supervision which is directly in charge of "sorting" inspection must be included. (Fig. 1.)

If failure costs can be obtained, such as

1. scrap material costs
2. scrap labour costs
3. rectification costs
4. customer placation costs
5. sorting inspection costs

the total amounts to the whole, or nearly the whole, of the present costs incurred by the failure of the company and its suppliers to control quality at the point of manufacture, and constitutes the gold mine from which it is hoped to extract much more than will be incurred in putting in proper "Control of Quality".

Now, it is pretty certain, at least in the engineering field, that the total "Failure" costs will amount to a sizeable total in hard cash, relative, of course, to the activities and size of the company. But even at this stage they will be convincing enough to get agreement that it is "worth looking into".

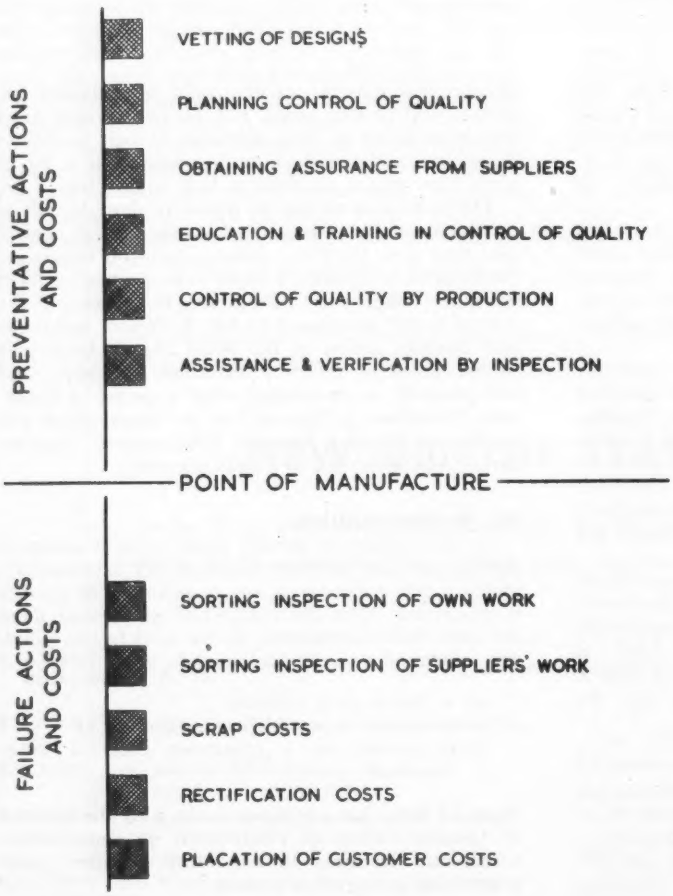


Fig. 1.

The next step will be to consider what steps towards Control of Quality it is proposed to take. *All* of them will necessarily be in those activities which take place before or during the act of making —"Preventative Costs"—and many of them will be in the shape of requests for time and consideration to be given by those concerned with pre-production activities to the need for ensuring that production *can* be certain of achieving the quality needs specified on the drawing, etc., and that it *will* be certain.

design

Starting with design, does a qualified Production Engineer, before the design is sold to the customer, agree that all requirements stated can be achieved? If not, as it is plain commonsense to do so, a *cost* will be incurred in checking designs for this factor.

planning

Secondly, does the Production Planner, after specifying the means of production, assess the fallibility remaining in the method he has specified and lay down checking procedure by production people to obtain verification that parts are correct? If not, as it is again plain commonsense to do so, an added cost in planning time and possibly also inspection equipment will be incurred.

production

Thirdly, does the floor-to-floor time allowed also include time to check according to the planned instructions? If not it must be so allowed, or additional personnel attached either to Production or to Inspection must be provided. Regrettably it will be found in some cases that time *is* allowed but due to absence of records and laxity of supervision, the pieceworker, understandably, devotes the quality check time to belting out components.

Nothing will replace adequate supervision in such a situation but it will be obvious that supervision can be assisted in several ways in assurance that checks *are* made.

Anyway, if extra time is going to be required then it must be transferred into cost and added to the total preventative costs.

Now quality is abstract and it will be discovered that by far the greatest need is a change in the attitude of minds. Somehow, it has to be brought home to all those involved in pre-production or production activities that they—and only they—decide whether things are made correctly or incorrectly. If there has been in existence for a long time a large sorting inspection force, it will be a stern struggle to convince people that such inspection isn't the best protection, but it must be done. Therefore, someone who *believes* in controlling quality in the right way has to do a lot of evangelical work by lecturing, demonstrating and helping. Dependent on the size of the company this will cost money and should again be added to the preventative costs.

Apart from probable changes in paperwork such as Operation Sheets, etc., the preventative cost side is about complete, and can now be added up :

1. Design—vetting by Production Engineer.
2. Planning control of quality simultaneously with planning production.
3. Extra equipment for checks at production point.
4. Time for checking at production point.
5. Altered or increased paperwork.
6. Education in control of quality.

Do not forget to deduct from these costs those which already exist, such as equipment not being used in the right place; also, probably checking time at the production point which may be allowed but is not being used. It will be surprising if you find that you are going to be landed with a very formidable amount of extra "preventative" costs.

For example, in one company only 10% extra planning cost was involved in properly planning Control of Quality.

We now have the two costs, existing "Failure Costs" and proposed "Preventative Costs", and it must now be estimated how much the former may be reduced by application of the latter.

Experience of other companies can be a guide. For example, in one large automatics shop scrap costs were reduced by 50% of the previous total, rectification costs by 30% and inspection costs by 27% within one year of instituting changes and operating on the lines indicated. Enquiry will uncover much information and it is hoped that in future issues of "The Production Engineer" case histories will be published which will assist.

Far better than such records, however, is to take a small representative section in your works and prove it yourself.

One factor previously touched on is the cost of verification of incoming supplies. Subsequent articles will cover this more fully but obviously the action required is simple. Find out *why* you are having to check and ponder on the benefits to be obtained if you could receive goods of certified quality, knowing that the certification was valid.

control by suppliers

Investigation into the Control of Quality exercised by suppliers will pay hand over fist. It will, quite likely, be found that the cheapest, from a strictly purchasing viewpoint, is costing more than it should, due to the added costs incurred by sorting in your own company, and delays resulting from non-delivery of acceptable parts. Co-operation, however, is the key to the solution in quality from suppliers. Agreement on such stands as appearance, finish, etc., is obviously a necessity, and in many cases a long-standing difficulty can be resolved by slight alterations to design which are acceptable.

The direct savings which can be placed in the balance sheet on the credit side of improved Control of Quality is, of course, reduction of the costs of "Bought Out" or "Suppliers" Inspection, but these are not the whole of the benefits which can result and in many companies they amount to a considerable figure in hard cash.

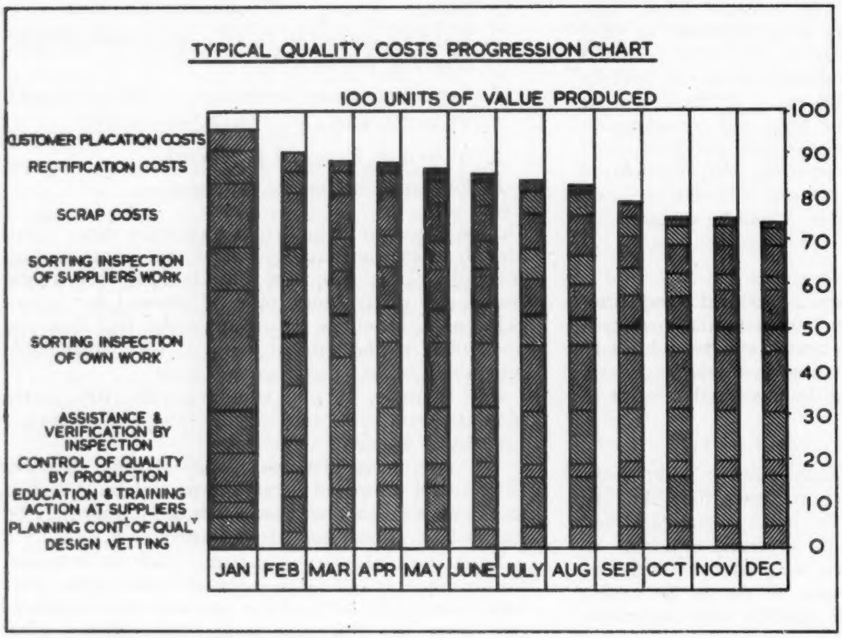


Fig. 2.

Difficulties will be encountered, but £ s. d. on the right side is an ally which commands universal respect.

It is, of course, impossible to lay down a general standard of achievement; what *is* important is to be able to show a reduction in the existing cost position. This should be a constant appraisal at intervals generally dictated by the company's costing procedure, often monthly. Fig. 2 shows one method used to examine and publish progress. It is necessary of course to have available figures, preferably in monetary value, of the value of goods produced during the period in question—not the overall value, but the increase in value caused by processing, which is simply the money paid for incoming supplies subtracted from the sales value.

This can be shown as a constant 100% on the chart and all costs of quality control shown as a percentage. Another method (given in the actual chart published) is to take the value of piecework hours produced in the period as the achievement standard.

It is not important what method is used to show the value of production, but it is essential that it is a known company standard and is generally accepted as a target of achievement.

The object is solely to illustrate continuously the relation of quality control costs to such achievement, with the progressive reduction which is certain to be achieved if the principles of Control of Quality at the point of production are conscientiously applied.

"Computers in Industry"— concluded

audience. The day's proceedings were rounded off by Dr. T. U. Matthew, Vice-Chairman of the Birmingham Section, who, in summing up, crystallised a number of interesting thoughts which had been aroused during the day. He emphasised that a spirit of enterprise was required in applying computers to everyday problems and said that most of the applications mentioned during the Convention had been undertaken in one of the large industrial companies. He underlined the need for imagination and initiative on the part of the production engineer in applying computers to solving these problems.

The proceedings concluded at about 6 p.m. after a stimulating and interesting day's programme which was appreciated by all those present.

The Convention was held in the Department of Mechanical Engineering at the University, by kind permission of Professor A. S. Tobias.

The Sir Walter Puckey Prize

The Institution is pleased to announce the first award of the Sir Walter Puckey Prize, to **Mr. L. C. Lambert,** of The Welsh College, Cardiff, for his project on " Friction Welding."

A very excellent project, on " Automatic Control of Grinding ", and worthy of special mention, was submitted by **Mr. J. H. W. D'Arcy Evans,** of The Woolwich Polytechnic.

The Sir Walter Puckey Prize is an Annual Award of £50 for the outstanding project on a Production Engineering Subject in a Diploma in Technology (Eng.) course, and is open to students taking such a Diploma course in any branch of engineering. Projects were received from the Loughborough College of Advanced Technology; The Welsh College; and The Woolwich Polytechnic.

Mr. E. W. Hancock, O.B.E.

It is announced by Production-Engineering, Ltd., that **Mr. E. W. Hancock,** O.B.E., Honorary Member and Past President of the Institution, has joined the company as an Associate Consultant. He will advise on factory planning and industrial development at home and abroad. He has also recently joined the Board of Brooke Tool Automation, Ltd., Birmingham.

Mr. Hancock, who retired earlier this year as Director of Special Projects for the Rootes Group Manufacturing Division, represents The Institution of Production Engineers on the Governing Board of The Lanchester College of Technology, Coventry.

S.A. Graduate's Achievement

Mr. Bennet Youngworth, Grad.I.Prod.E., recently gained the 1959 Student Award of the Institution of Production Engineers in South Africa.

This Award is given annually to the student obtaining the highest aggregate marks in the production engineering subjects of the National Engineering Examinations. Mr. Youngworth gained distinctions in the three subjects concerned: planning, costing and estimating; time and motion study; and works organisation and management. He is at present studying industrial engineering at the University of Houston, Texas.

Reconstitution of B.C.A.C.

It is anticipated that the reconstitution of The British Conference on Automation and Computation, formally brought into being at the annual meeting on 10th October last, will result in more effective operation.

The objects of the new body are (a) to stimulate interest in, spread knowledge of and foster the development and applications of automatic control and computation; (b) to afford a common meeting-ground for the constituent organisations; (c) to encourage presentation of British papers at international conferences; and (d) to maintain liaison with other countries which support such international conferences.

The 31 constituent societies include The Association of Certified and Corporate Accountants, The Institute of Cost and Works Accountants, The Chartered Institute of Secretaries, The British Computer Society, The British Institute of Management, The Institution of Electrical Engineers, The Institution of Mechanical Engineers, The British Productivity Council and the Trades Union Congress, with the D.S.I.R. as observer.

Sir Walter Puckey, M.I.Prod.E., has been elected Chairman of the Conference.

Retirement of Mr. H. C. Town

The retirement of **Mr. H. C. Town,** Member, Head of the Engineering Department of Keighley Technical College for over 30 years, is announced.

Mr. Town is widely known as the author of textbooks dealing with machine tools and allied subjects, and has presented many Papers to various Sections of the Institution throughout the United Kingdom.

He was twice awarded the Water Arbitration Prize of The Institution of Mechanical Engineers for Papers dealing with " Hydraulic Operation of Machine Tools ", and has gained The Institution of Production Engineers' Medal for the Best Paper by a Member.

His many friends in the Institution and throughout the profession will wish Mr. Town a long and happy retirement.

"COMPUTERS IN INDUSTRY"

Fourth National Students' and Graduates' Convention, Birmingham, 17th September, 1960

THE Fourth National Students' and Graduates' Convention on the theme: "Computers in Industry" was held at the University of Birmingham on Saturday, 17th September, 1960. This meeting was organised by the Birmingham Graduate Section and was attended by about 170 delegates from as far afield as Halifax and Southampton.

The aim of the Convention was to give an appreciation of the development and application of computers in industry and was particularly directed to those with no previous knowledge of the subject. The principal speaker was The Rt. Hon. the Earl of Halsbury, Immediate Past-President of the Institution, who was supported by three other speakers. The Lord Mayor of Birmingham was also present, and extended a Civic Welcome to the Delegates.

The day's proceedings opened with a welcome from the Convention Chairman, Mr. D. Edwards, to all those attending, and after a brief introduction, the first paper, "Computers Simply Explained", was delivered by Lord Halsbury. Taking familiar objects as examples, he constructed on the blackboard what he described as a "Heath Robinsonian Computer". By simple steps, using the analogies of clocks and telephone exchanges, Lord Halsbury built up a very clear picture of the essentials of digital computers. This included an explanation of the binary arithmetic system, and the elements of programming. Mr. B. E. Stokes, M.I.Prod.E., a past Chairman of the Birmingham Graduate Section, opened the discussion.

civic welcome

At coffee, the Lord Mayor of Birmingham (Alderman Garnet B. Boughton), joined the Convention and expressed his pleasure at being able to attend. In his address, he stressed the need for remaining competitive in world markets by every possible means, and emphasised the economic dangers from the rapid advances in Russian technology. He concluded by extending a Civic Welcome to the delegates, and wished every success to the Convention.

The second paper, "The Use of Computers for Optimal Planning", was then delivered by Mr. C. M. Berners-Lee, of Ferranti Ltd. Using the homely illustrations of balancing pig-food diets and washing up knives and forks, he demonstrated the basic principles of optimal planning and led up to the application of this procedure to the programming of an engineering works. The discussion was opened by Mr. F. W. Cooper, Institution Education and Technical Officer.

After lunch at the Guild of Undergraduates' Union, the Convention split up into two groups. Approximately 50 members saw a film on the operation of the Ferranti "Pegasus" digital computer, together with films on the application of computers to machine tool control and oxy-acetylene profile cutting.

production control by analogue computer

The remainder of the Convention members heard Mr. W. G. Ainslie, of the University of Birmingham, deliver his Paper on "Research on Production Control by Analogue Computer". Mr. Ainslie very clearly explained the principles of analogy and by referring to mechanical and electrical models, demonstrated how dynamic systems can be simulated. He suggested that under certain conditions the factory could be likened to a "black box". He referred to the earlier works of certain economists and suggested that quite complex economical systems might also lend themselves to analogue computation. Mr. Ainslie did much to put in perspective the analogue computer in relation to its better-known brother, the digital computer. After tea the delegates reassembled for the final Paper on "Computers—Retrospect and Prospect", given by Mr. G. M. Davis of The English Electric Co. Ltd. Mr. Davis explained how the essential items of computer equipment had developed over the years and indicated likely developments in the future. He stressed the comparatively short length of time in which the machines have developed and the rapid progress which is continuing. He concluded with a very quick look into the far-distant future where he, not too seriously, envisaged the whole of the national economy, all international trade and music and art being directed and operated by computers—in short, "a world fit for computers to compute in". Mr. L. W. Bailey, M.I.Prod.E., Chairman of the Production Control Sub-Committee, opened the discussion.

brains trust

A Brains Trust then followed in which the speakers replied to a number of interesting questions from the

(*continued on page* 728)

news of members

Mr. H. H. Evans, Member, has joined the Board of Brooke Tool Automation, Ltd., Birmingham, as Production Manager. He was formerly General Factory Manager and Director of Personnel Development at Cincinnati Milling Machines, Ltd., and a Director of Hordern, Mason and Edwards, Ltd.

Mr. W. A. Handley, Member, formerly Production Controller to Dowty Hydraulic Units, Ltd., is now a Director of Designex (Coventry) Ltd., a new company of the Dowty Group.

Mr. H. S. Holden, Member, is now Managing Director of Brooke Tool Automation, Ltd., Birmingham.

Mr. John R. Kelly, Member, Director of Vickers-Armstrongs (Engineers) Ltd., and General Manager of the Elswick and Scotswood Works, Newcastle, retired recently after 34 years with the Vickers-Armstrongs organisation.

Mr. S. W. D. Lockwood, O.B.E., Member, Director and General Manager of Sir W. G. Armstrong-Whitworth Aircraft, Ltd., Coventry, for over five years, and a member of the firm since 1921, is now Managing Director.

Mr. Allan Ormerod, Member, General Manager of Ashton Bros. & Co. Ltd., Hyde, has been elected President of The British Association of Managers of Textile Works. He is also a member of the Weaving Research Committee of the British Cotton Industry Research Association, and of the Redeployment Committee of the Federation of Master Cotton Spinners.

Mr. F. Stafford, Member, has been appointed a Director of the Motor-Car Division of Rolls-Royce, Ltd. Mr. Stafford is the Company's General Works Manager at Crewe, where he has been for the past 12 years.

Mr. B. E. Stokes, Member, has moved from the Clutch Division, Borg & Beck, Ltd., to Lockheed Hydraulic Brakes, Ltd., Leamington Spa. Mr. Stokes is the Immediate Past Chairman of the Editorial Committee and serves on the Finance and General Purposes Committee.

Mr. A. T. Allsop, Associate Member, Manager of the Clacton Division of the Foster Instrument Company, Ltd., Letchworth, since 1953, has been appointed a Director of the Company.

Mr. B. C. Bennett, Associate Member, has been appointed Sales Engineer (Machine Tools) with Alfred Herbert, Ltd., and is responsible to the Birmingham office for the South Wales Area.

Mr. Peter Black, Associate Member, is now Senior Lecturer in Mechanical Engineering at the Mid-Essex Technical College, Chelmsford.

Mr. A. E. Capper, Associate Member, is now Plant Engineer with the Northern Electric Company, Ltd., London, Ontario.

Mr. R. W. Edwards, Associate Member, formerly Chief Production and Planning Engineer with Bristol Cars, Ltd., is now Production Works Manager with Aston Martin and Lagonda Cars, Ltd.

Mr. A. Gordon, Associate Member, has been appointed Manager of a new Production Engineering Department formed at the Newhouse (Lanarkshire) factory of Honeywell Controls, Ltd. Mr. Gordon joined the Company three years ago, during which time he has established a Quality Department.

Mr. F. Howarth, Associate Member, is now Manager of Technical Sales and Product Development with the Extended Surface Tube Company, Ltd., Birmingham.

Mr. Oswald F. Rendell, Associate Member, has relinquished his position as a Management Consultant with Urwick, Orr & Partners, Ltd., and is now a Consulting Production Engineer with T.I. Group Services, Ltd., Birmingham.

Major R. A. Staker, Associate Member, is now Technical Adviser to 16 Base Vehicle Depot, R.A.O.C., Advanced Base (B.R. Forces), B.F.P.O.21.

Mr. R. O. Watts, Associate Member, has been appointed Lecturer at The Forest of Dean Mining and Technical College, Cinderford, and will take up his duties on 1st January, 1961.

Mr. F. D. Duffin, Graduate, has been promoted from Welding Technician to Chief Inspector with The Hughes Tool Company, Ltd., Belfast.

Mr. D. W. Hall, Graduate, formerly with A.E.I. Ltd., Woolwich, is now a Development Engineer in the Fluid Power Division of the Baldwin Instrument Company, Dartford. At the recent inaugural presentation ceremony of the Associateships of Woolwich Polytechnic, Mr. Hall was the only student

to be awarded an Associateship for qualifying in Production Engineering.

Mr. R. Kirkaldy, Graduate, is now a Methods Engineer with Electrolux, Ltd., Luton.

Mr. L. E. Ramsbottom, Graduate, is now Chief Draughtsman with Tubes, Ltd., Kirby Muxloe, Leicester. He was formerly with the Talbot Stead Tube Company, Walsall.

CORRECTION. In the October issue **Mr. J. Harrison,** Head of the Engineering Department of Dacorum College of Further Education, Hemel Hempstead, was described as a Graduate member when he is, in fact, an Associate Member.

DIARY FOR 1961

JANUARY 25 ... ... **The 1961 Lord Sempill Paper,** at The Royal Aeronautical Society, London, at 6.30 p.m. (See Supplement to this Journal.)
(changed date)

Speaker: **Sir Percy Hunting,** F.C.I.S.

Subject: **"The World's Future Transport Requirements."**

JANUARY 26 ... ... **Annual General Meeting,** 10 Chesterfield Street, Mayfair, London, W.1, at 2 p.m.

NOVEMBER 1 ... ... **Annual Dinner,** Dorchester Hotel, London.

BINDERS FOR "THE PRODUCTION ENGINFER"

The Institution is able to supply the "Easibind" type of binder, in which metal rods and wires hold the issues in place, and which is designed to hold six issues.

It will be found that copies of "The Production Engineer" can be quickly and simply inserted into this binder, without damage to the pages, and that binding six issues at a time, instead of twelve, will facilitate easier reference and handling of the volumes.

The binders may be obtained from: The Publications Department, 10 Chesterfield Street, Mayfair, London, W.1, price 10/6 each, including postage. Date transfers, for application to the spine of the binder, can be supplied if required, price 6d. each. (Please specify the year required.)

Hazleton Memorial Library

ADDITIONS

Members are reminded of the following Library rule, which is frequently ignored:

"The initial loan period is one month, and borrowers may keep books and periodicals for further periods of one month, if they ask the Librarian, and if no other borrower wants them. Applications for renewal may be made by post or telephone."

Averbach, B. L. **"Tool Steels."** *New York, Climax Molybdenum Company,* 1960. 32 *pages. Illustrated. Diagrams.*

The author is on the staff of Massachusetts Institute of Technology. He discusses the principal types of tool steel that contain molybdenum, summarises some aspects of the heat treatment and microstructural constituents, and pays particular attention to the hot hardness of these steels. The factors which influence dimensional behaviour are discussed and some typical applications of tool and die steels are shown.

Board of Trade. **"Index of Industries and Products, with the Government Departments Principally Concerned."** *London, Board of Trade, February,* 1960. 34 *pages.* 2s. *including postage.* (Obtainable from the Board of Trade Library.)

Boehm, George A. W. and the Editors of *Fortune*. **"The New World of Mathematics."** *London, Faber & Faber,* 1959. 128 *pages. Diagrams.* 10*s.* 6*d.*

This work appeared firstly as a series of articles in the American magazine, *Fortune*. The series set out to "convey the new feeling of mathematics to its nation-wide readers", and to impress on the public the importance in this age of the science of mathematics.

Contents include: the "group" concept, the Intuitionists, Motivation, new uses of the Abstract including the "games theory", and the "random walk" theory, Roulette by Computer, the Monte Carlo method and an appendix covering some mathematical recreations, old and new, such as the paths on a doughnut and the paradox of the middle thirds. The book is intended for the layman.

Butler, J. **"Compression and Transfer Moulding of Plastics."** *London, Iliffe for the Plastics Institute; New York, Interscience Pub.,* 1959. 230 *pages. Illustrated. Diagrams.* 35*s.*

This work forms part of the Engineering Series of the Plastics Institute edited by H. Barker. The original monographs available only to members of the Institute have been revised and new ones added to cover latest developments in each branch. The sections on compression moulding and moulds are new but the part on transfer moulding is almost wholly the material of the original monographs.

Carter, C. F. and Williams, B. R. **"Science in Industry, Policy for Progress."** (On behalf of the Science and Industry Committee.) *London, O.U.P.,* 1959. 186 *pages.* 21*s.*

This is the third of a series of Reports written for the Science and Industry Committee. The first two Reports, *Industry and Technical Progress,* and *Investment in Innovation,* deal with the factors which determine the speed of application of new scientific knowledge in industry. This book covers suggestions for policy which should be taken by industry and the Government to implement such ideas.

Action should be taken by industry in regard to such matters as work study, production, general communication of ideas, the use and conduct of research and development and the finance of innovation. In order to assist, the Government should concentrate more on such factors as aid for research and development, education, taxation, credit, foreign trade, and the control of restrictive practices.

Chapanis, Alphonse. **"Research Techniques in Human Engineering."** *Baltimore, John Hopkins Press,* 1959. 316 *pages. Diagrams.* 48*s.*

Discusses the problems and techniques of "human engineering", that is, ways of designing machines and operations so that they match human capacities and limitations.

Contents: Introduction — Methods of direct operation — Methods for the study of accidents and near accidents — Statistical methods — The experimental method — Some special problems in experimenting with people — The psychophysical methods — Articulation testing methods — Bibliography.

Cotton Board, Manchester. **Papers prepared for the Cotton Board Spring Productivity Conference on Mill Management in the nineteen-sixties.** Lytham St. Annes, 26th - 28th February, 1960. *Manchester, Cotton Board Productivity Centre,* 1960. 55 *pages.*

Contents: Gregory, H. G.—The role of the production engineer; Hodara, Ralph—Implications of re-equipment; Crow, W. C.—Implications of multi-shift working; Reporting back of discussion group leaders — Winterbottom, W. T. Concluding remarks.

Dennett, Herbert. **"Unit Stock and Store Control."** *London, Business Publications,* 1957. 194 *pages. Illustrated.* 25*s.*

A useful textbook on the subject of stores control.

Contents include: The purpose of unit control, single shop retailer stocks, small multiple store stocks, large multiple, the store, wholesalers, manufacturers, The principles of unit stock control; Manual systems of stock control; Semi-automatic methods of control; Automatic methods of control; Special applications of unit stock control in, *inter alia,* jewellery trade; shoe shops, carpet manufacturers, retail bakery and grocery trade; a co-operative ordering scheme

Dombrow, Bernard A. **"Polyurethanes."** *New York, Reinhold; London, Chapman and Hall,* 1957 (*Rep.* 1960). 176 *pages. Illustrated. Diagrams.* (Reinhold Plastics Applications Series.) 36*s.*

Surveys the properties and applications of polyurethanes. Like the other books in the Plastics Application Series this one is essentially a book for the user of plastics who, it is assumed is not necessarily a chemist. The chemical side of the subject, is, therefore, presented in a simple manner.

Contents: Introduction — Chemistry — Rigid foams — Semi-rigid foams — Flexible foams — Rubbers — Adhesives — Coatings — Textile applications — Miscellaneous — Handling of disocyanates — Bibliography.

Investment Casting Institute, Chicago, Ill. **"How to Design and Buy Investment Castings."** Edited by Robert G. Herrmann. *Chicago, Ill., the Institute,* 1960. 165 *pages. Illustrated. Diagrams. Tables.*

Contents: What investment castings can do for you — Basic production techniques — What metal to use? — Investment casting from vacuum alloys — Determining quality of cast parts — Designing for investment castings — How to buy investment castings.

Journal Contents

Volumn 39, 1960

Subject Index to Papers Published, 1960

Author Index to Papers Published, 1960

Announcing a change of name

WAKEFIELD-DICK INDUSTRIAL OILS LTD.

will become

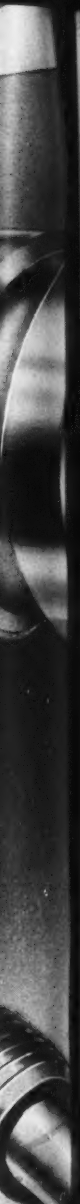
CASTROL INDUSTRIAL LIMITED

On the 2nd January 1961 we will, subject to the approval of the Board of Trade, change our name from Wakefield-Dick Industrial Oils Limited to Castrol Industrial Limited. Many customers have always called us the "Castrol Firm", yet some of our older friends will wish to know the reason for the change. Since the war, our world business has multiplied, and with the post-war generation it is the name Castrol which has the greater significance. Therefore, to simplify the identification of our group, we have decided that our Industrial Company will go forward under the Castrol name.

CASTROL HOUSE, MARYLEBONE ROAD, N.W.1. HUNTER 4455

Castrol INDUSTRIAL OILS

The new symbol for Castrol Industrial Limited



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1960/1961

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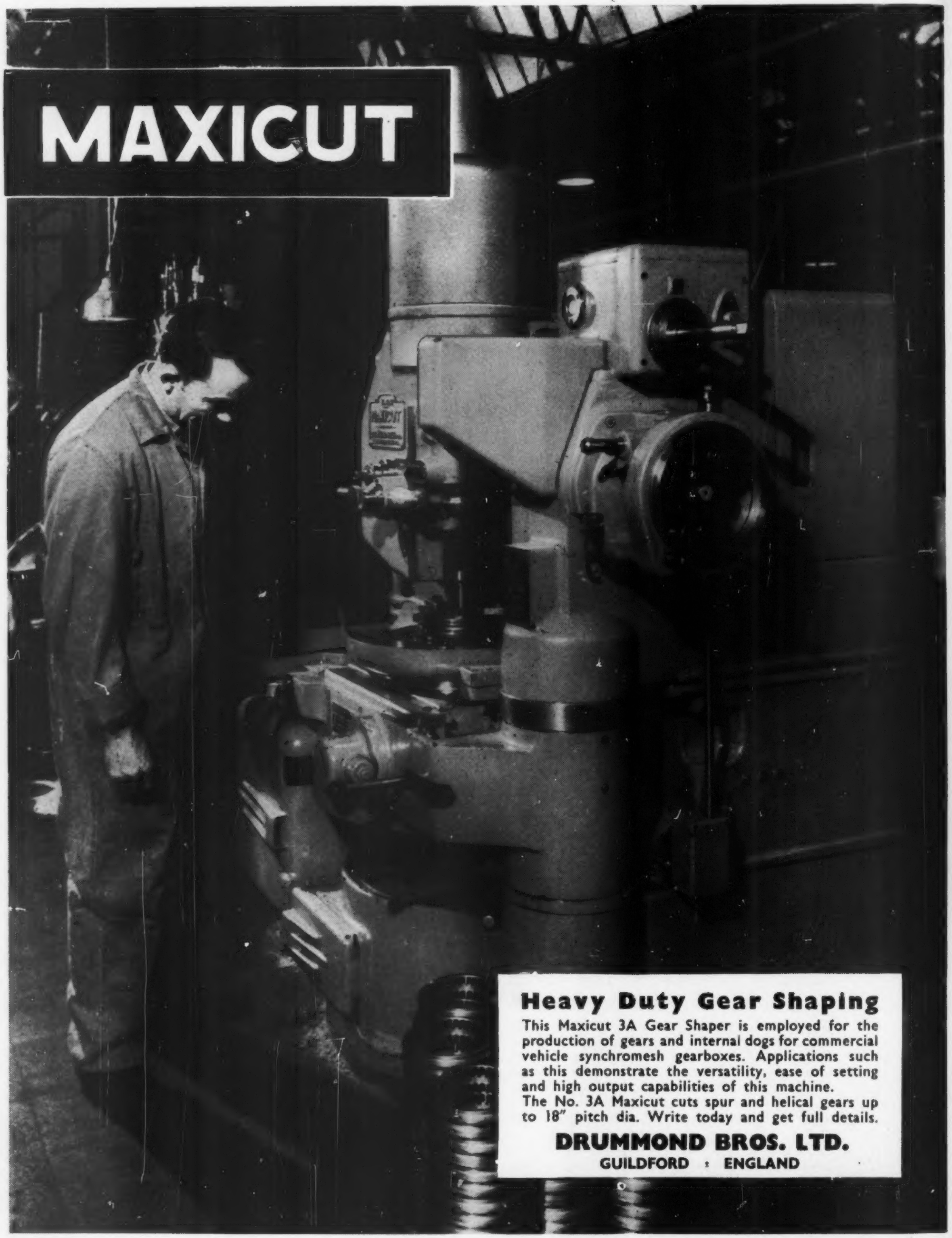
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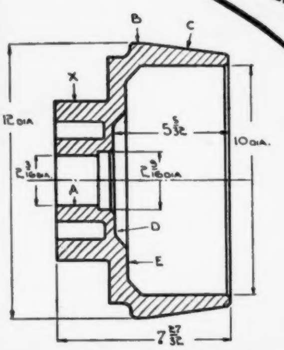

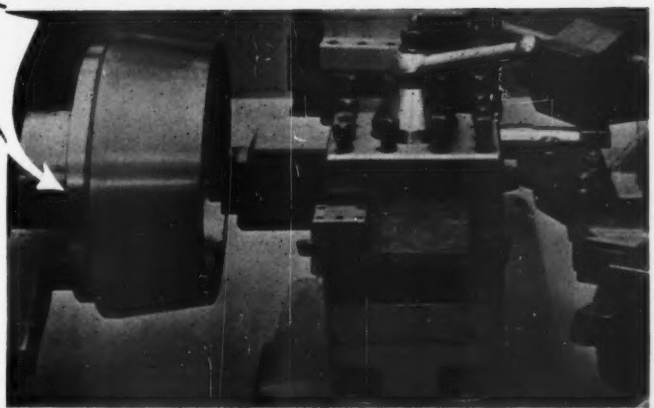

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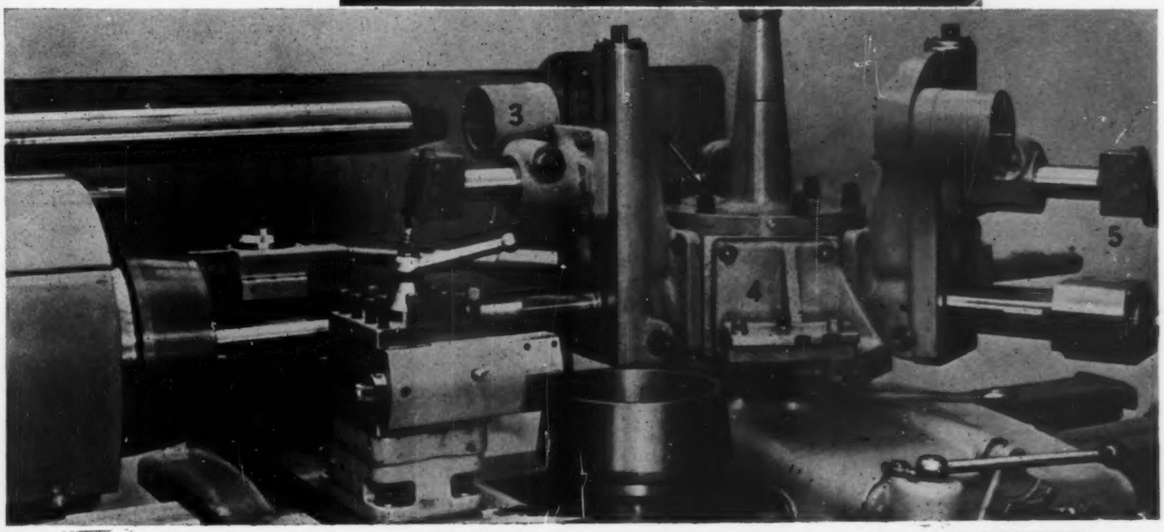
Floor-to-Floor Time:
$17\frac{1}{2}$ mins. each.

Tungsten Carbide Cutting Tools



DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
1. Chuck on X (using Loading Attachment)	1	—	—	—	Hand
2. Rough Bore A & $2\frac{9}{16}$" dia. and Chamfer	2	—	375	260	64
3. Face (2 Cuts) - - - - -	—	Front 1	93	278	64
4. Rough Bore 10" dia. Rough Knee Turn B and Rough Taper Turn C - - -	— 3	— Rear	75	240	44
5. Contour Face D & E (Rough & Finish) -	4	Front 3	93/125	242/325	64
6. Finish Bore 10" Finish Knee Turn B and Finish Taper Turn C and Chamfer 10" dia.	— 5	— Rear	125	390	64
7. Chamfer Outside Dias. - - - -	—	Front 2	125	390	Hand
8. Finish Microbore $2\frac{3}{16}$" dia. - - -	6	—	580	333	88
9. Remove (using Attachment) - -	1	—	—	—	Hand

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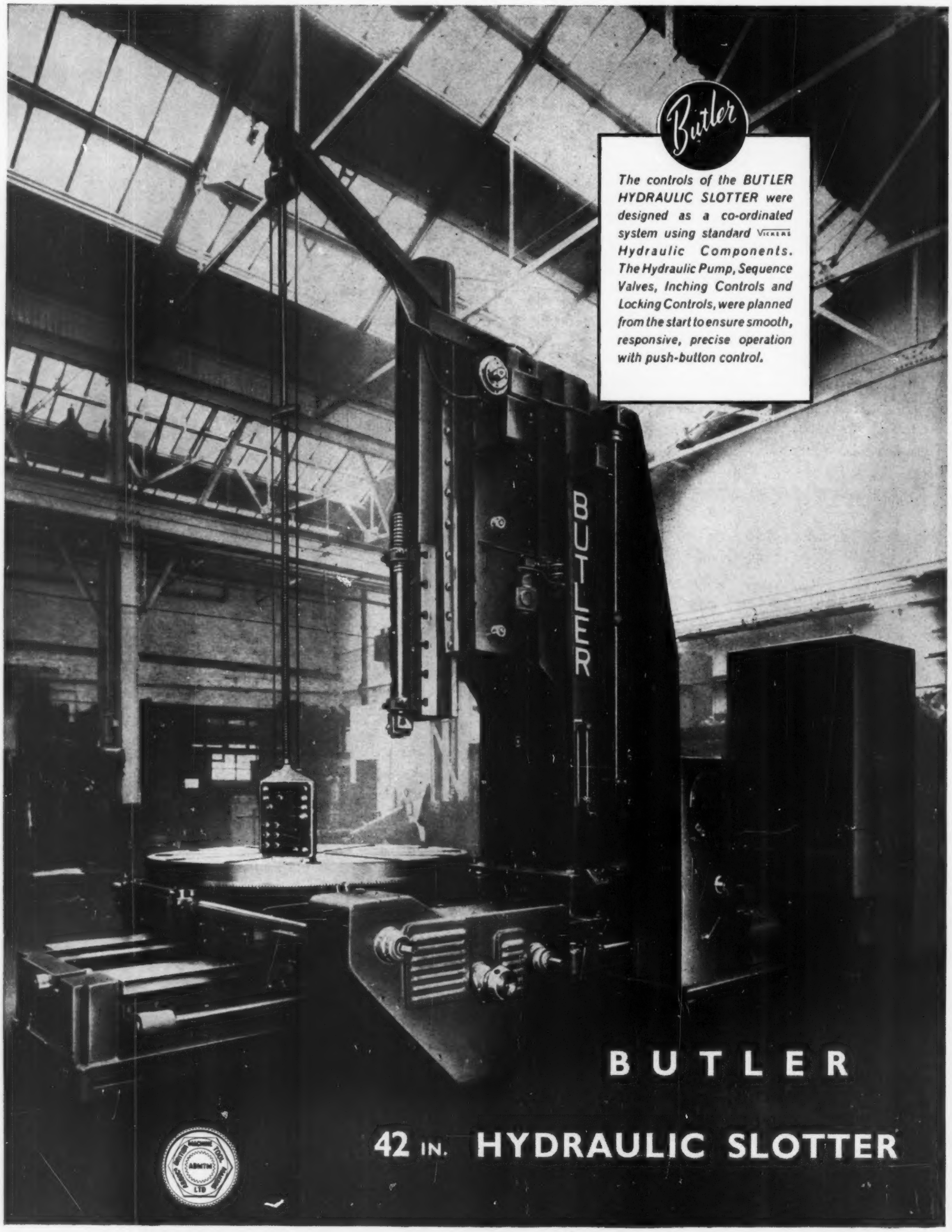
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Electrical Aids in Industry

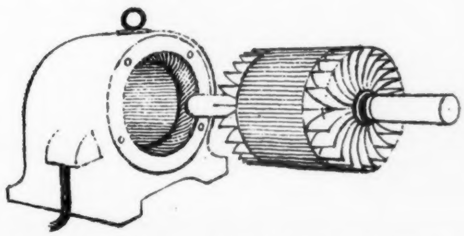
Data Sheet **No. 14**

Electric Motors & Controls 1

Most manufacturers today employ electric motive power through individual drives, which, among their many advantages, permit the right type of motor to be used for each of various types of machine. The range of motors available—each with its own characteristics–is very large, and the factory executive could well be guided in his choice by the expert views of the motor manufacturer, the installing engineer or his Electricity Board's engineer. The characteristics of the main types of motor are briefly summarised below.

Squirrel-cage Motors

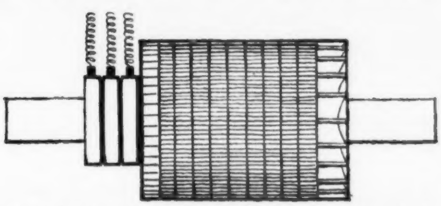
These are the most straightforward and simple in design, and are therefore relatively cheap and robust in character. They should be considered for general duties and, in conjunction with variable-speed gears or couplings, for applications requiring variable speeds, e.g. for crane drives. Small sizes can be switched direct-on-line.



The squirrel-cage motor is very suitable for individual drive of each motion of single-purpose machine tools where the motor horsepower can be precisely specified. It is suitable for driving pumps, fans, lifting hoists and woodworking machines. Textile machinery represents another field of use.

Slip-ring Motors

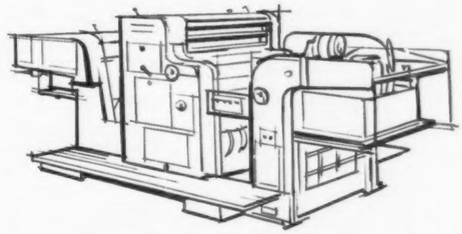
The chief advantage of the slip-ring motor is a very low starting current for a given torque, e.g. full-load torque at starting with a current about 10% above full-load current. This makes it suitable for applications requiring a prolonged starting period with a



load of high inertia. It also permits of speed variation below synchronous speed, though with some loss of efficiency. Typical applications include fans, pumps, heavy lathes, grinders and boring mills, as well as calendering machines, cable-laying-up machines and mine hoists.

Three-phase A.C. Commutator Motors

The main characteristic of this type is variable-speed with uniform and gradual acceleration and good efficiency over the speed range. Paper manufacture provides excellent examples of its use, e.g. in paper-making, reeling, cutting, calendering, coating and drying.



A.C. commutator motors are recommended for mechanised bakeries and for cranes and hoists where very slow speeds are frequently needed.

Synchronous Motors

These are constant-speed motors. One particular advantage is that they can be operated at unity or even at leading power factor to correct a system suffering from lagging power factor, and perhaps so qualify for a reduction in the electricity bill. Pump and compressor drives are typical uses to which they can be put. They are also used in motor-generator sets.

Single-phase A.C. Motors

In general, single-phase motors are used in light industries for drives not requiring more than about five horsepower or where a three-phase supply is not available. While their use is mainly limited to work of a light nature, they do fill a need in such duties as sewing-machine drives, portable hand tools, window opening and closing gear, etc.

Direct Current Motors

For a completely unfettered performance where wide ranges of speed variation, high rates of acceleration and powerful dynamic braking are all-important, the D.C. motor is unrivalled. This means in effect the installation of an A.C.-D.C. motor-generator set or rectifier to give the necessary supply, but the increased cost may well be compensated by the improvement in productivity. When variable voltage is applied to the armature, a wider speed range is obtainable than with any other type of motor. Typical applications of the D.C. motor are: cranes, haulage and tippler equipment, certain machine tools requiring a large speed range and smooth acceleration, high-speed printing and steelworks drives.

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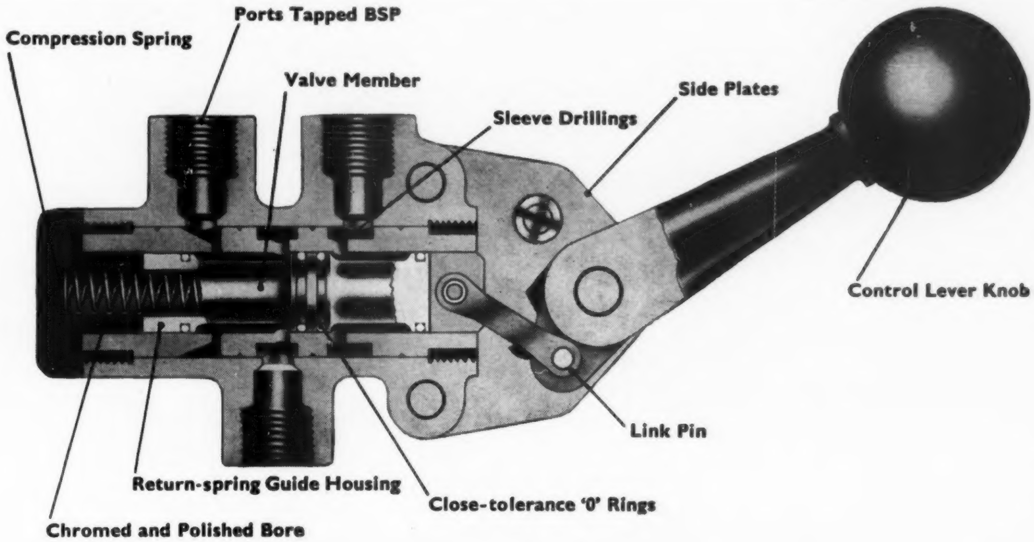

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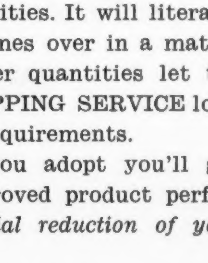

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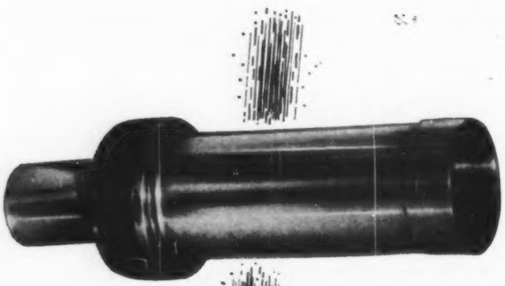

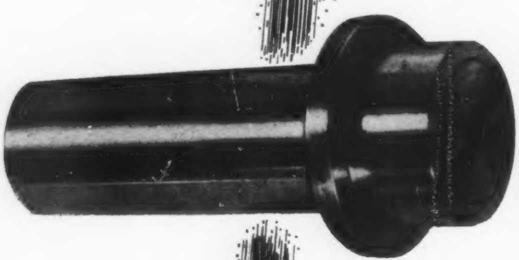

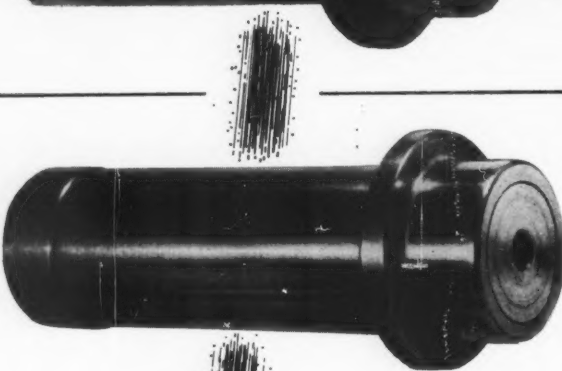

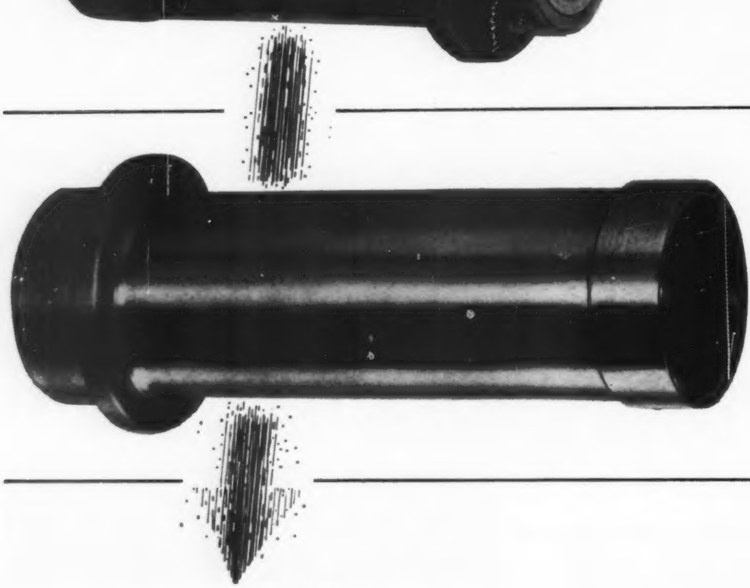

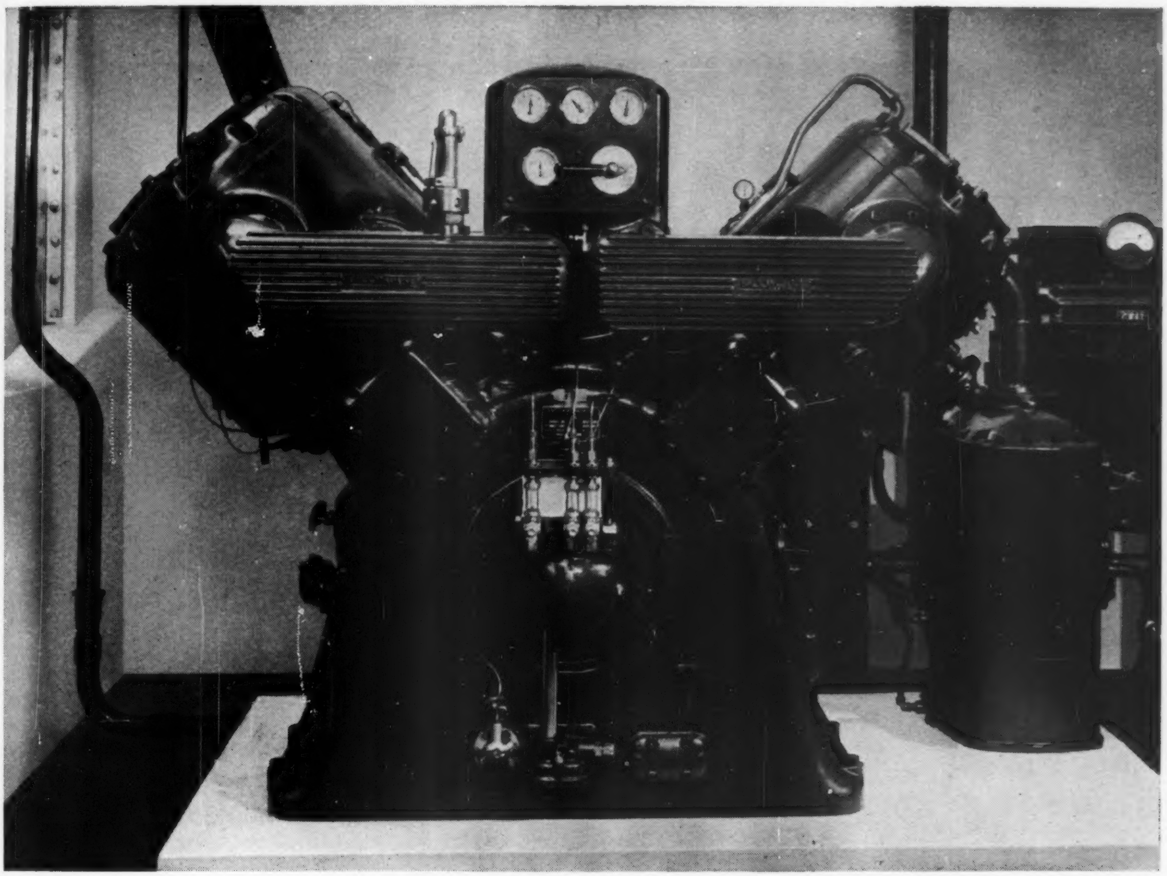

Type V500 delivering 525 c.f.m. of free air at 100 p.s.i.

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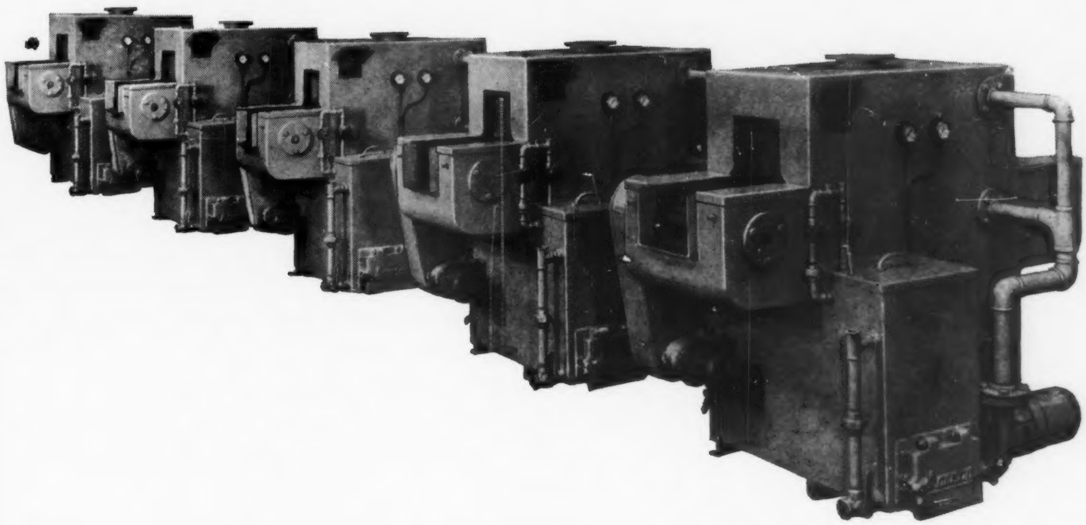

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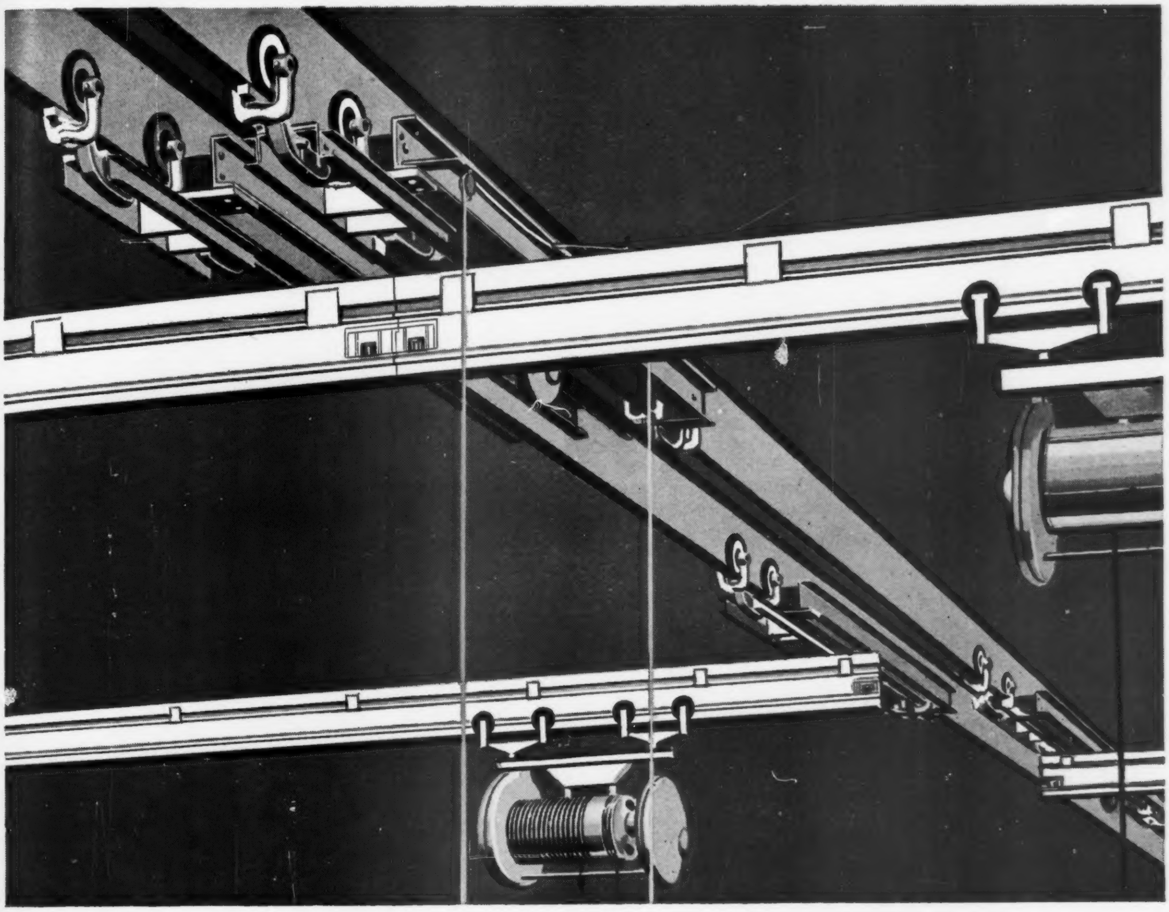
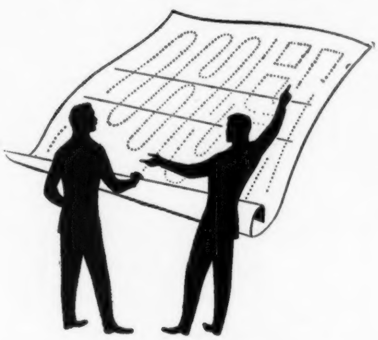


Unobstructed movement OVERHEAD with underslung interlocking cranes



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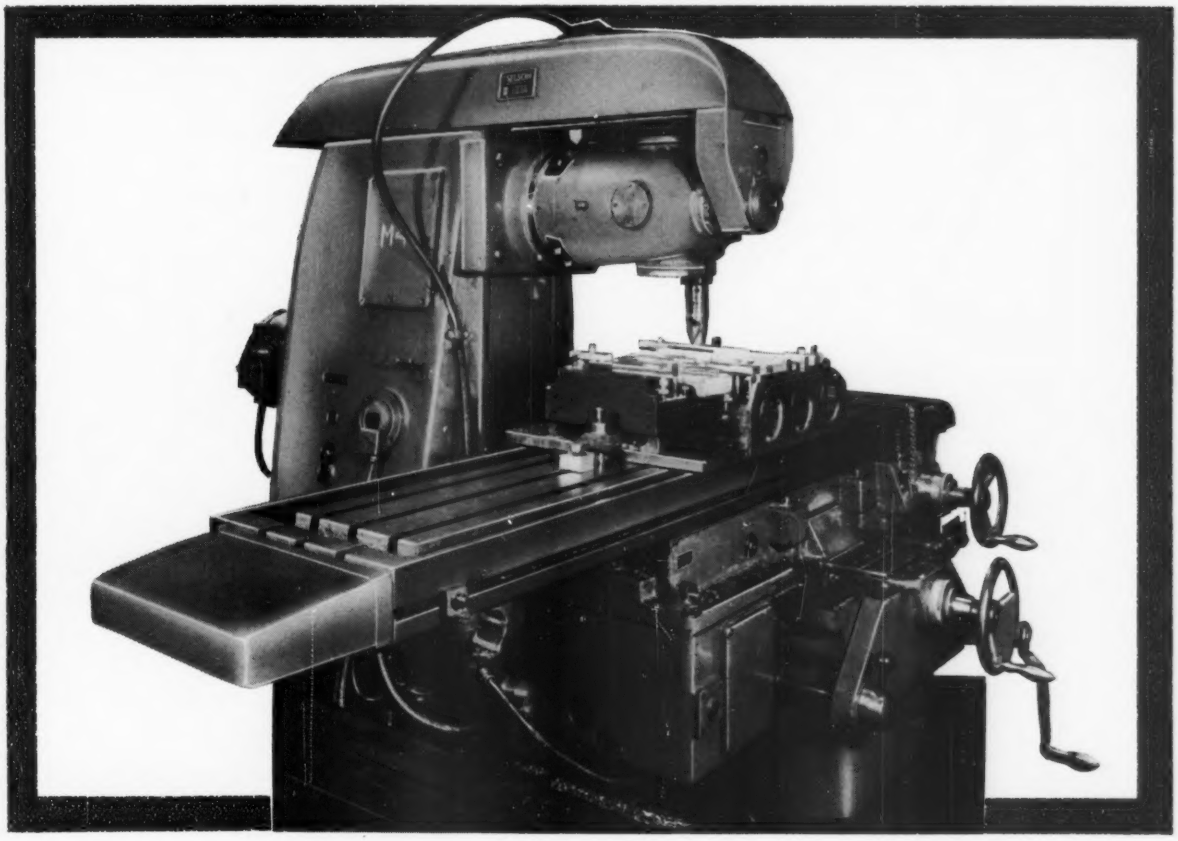

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Complete rigidity at high speed is a feature of the Zbrojovka Millers. The Machine illustrated is the FA5H Horizontal Miller in operation at the Farlington works of Messrs. C. J. C. Developments (Portsmouth) Ltd., who have courteously permitted us to publish this photograph. Write or telephone for full details.

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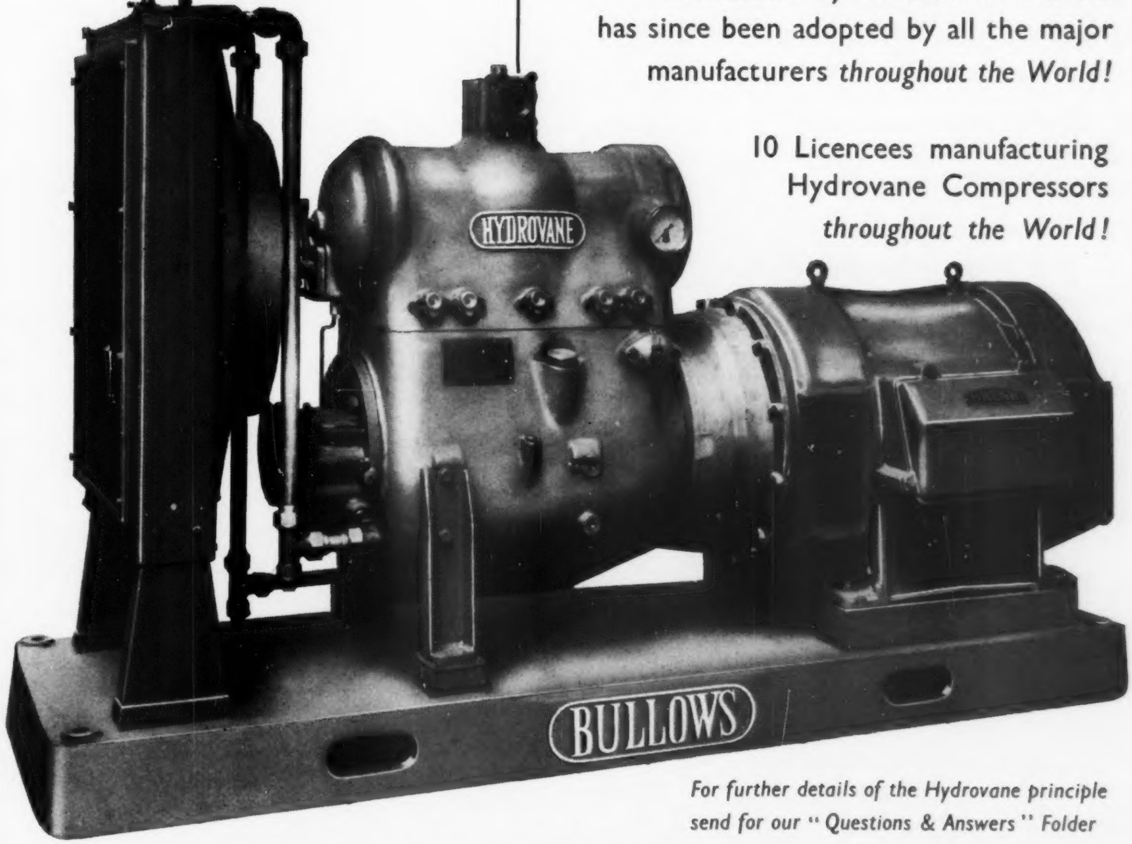
10 Licencees manufacturing Hydrovane Compressors *throughout the World!*



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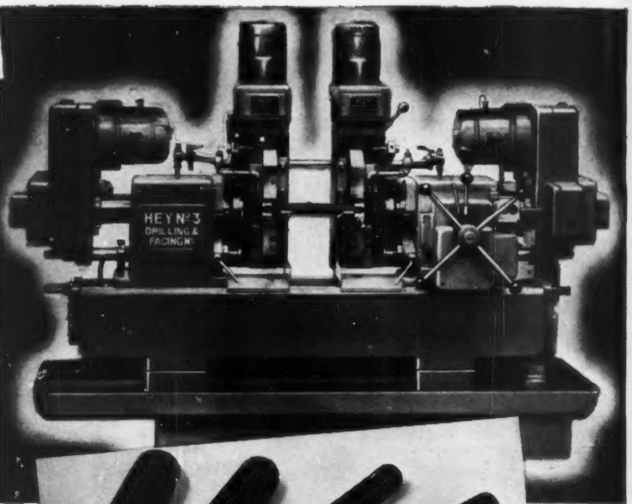

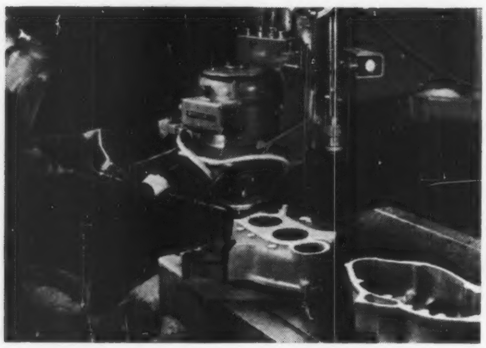


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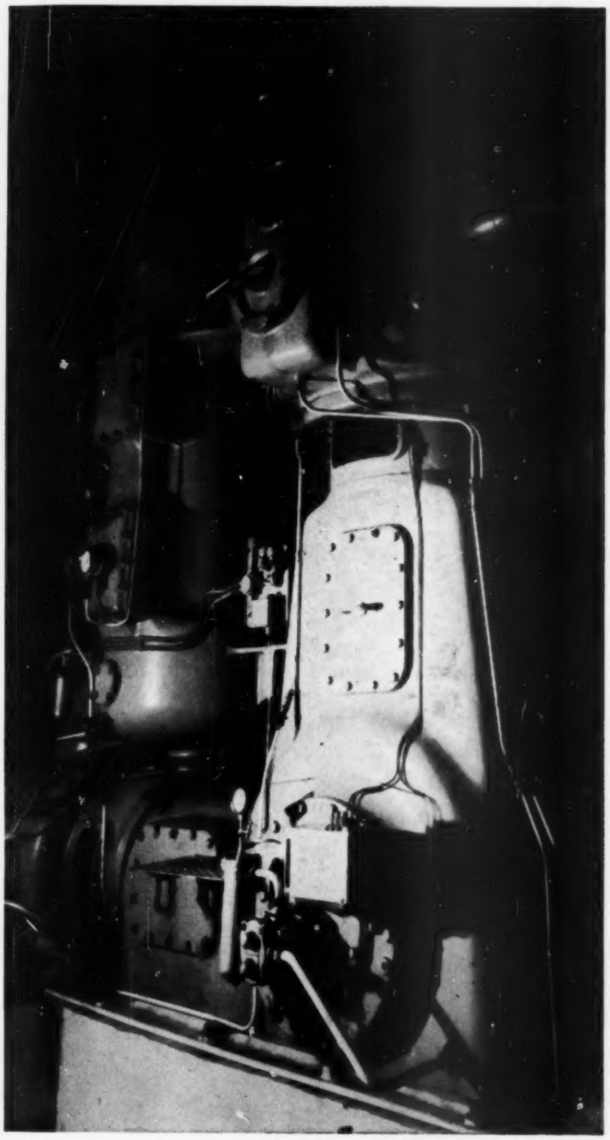

You'd be surprised at the different kinds of people who come to us for compressors—all with different problems on their minds. We'd like you to meet some of them. You may have a similar problem.

1. The man who's 'electrified' four times a year . . .

when he gets the power company's bill. Any compressor he buys must be easy on electricity. Atlas Copco can supply him with AR series, low-speed compressors designed for maximum operating economy.

2. The man who works in the desert . . .

at least it seems like the desert, judging by the cost of water. Atlas Copco make several types of compressors to suit him—such as completely air-cooled types with air-blast intercoolers to maintain delivery temperatures comparable to those of water-cooled units.

3. The man whose floor space costs the earth.

His factory site is expensive and he's made the most of it. Short of enlarging the compressor house, he has only a few square feet in which to install new machines. Atlas Copco has the answer: a range of compact, well-balanced compressors such as the ER series.

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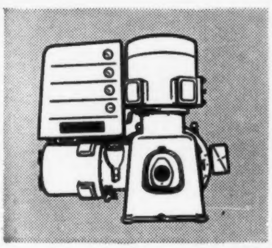
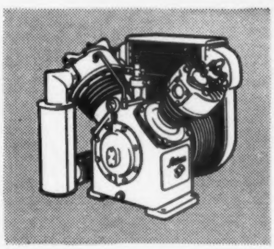
With companies or agents in ninety countries, Atlas Copco is the largest organisation in the world specialising solely in compressed air equipment. Products include stationary and portable compressors, rock drills, loaders, hoists, air tools and paint-spraying equipment. Wherever you are the international Atlas Copco group offers expert advice on the selection of equipment and provides a complete after-sales service.

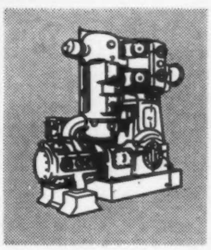
WRITE FOR THE LITERATURE Leaflets describing Atlas Copco stationary compressors are readily available on request. Write, giving some indication of the types of machines you are interested in, to your local Atlas Copco company or agent or to the address below.



ER 6



NT 9



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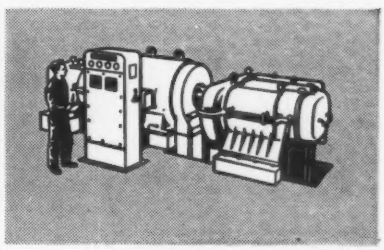

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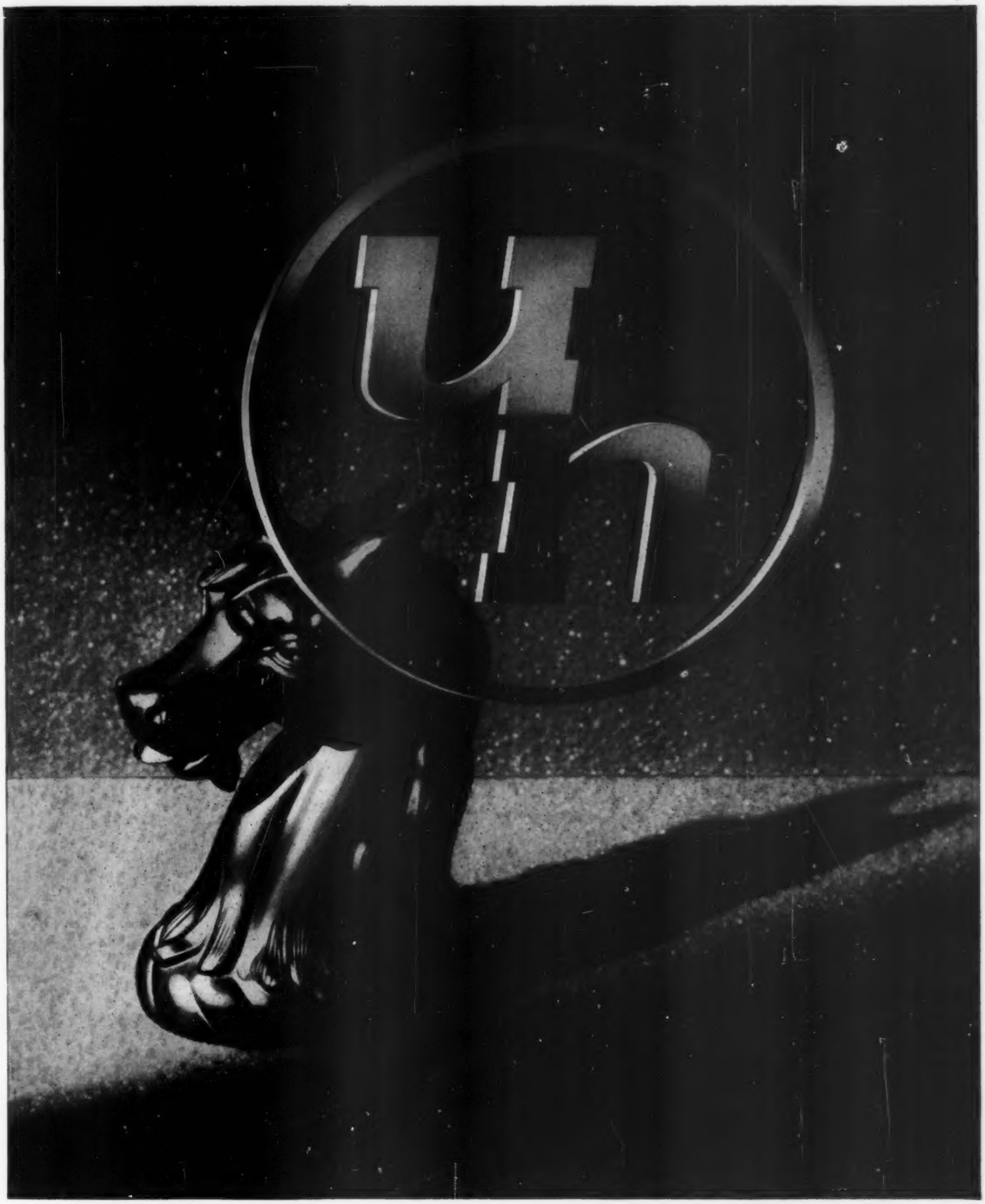

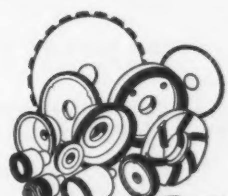

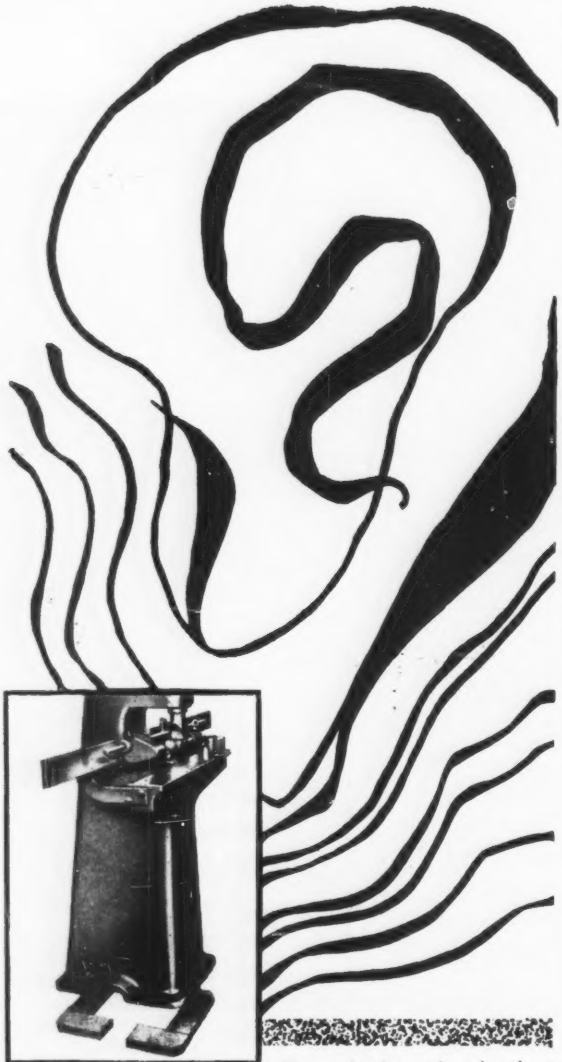

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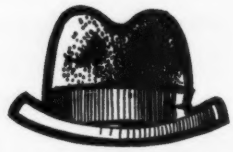
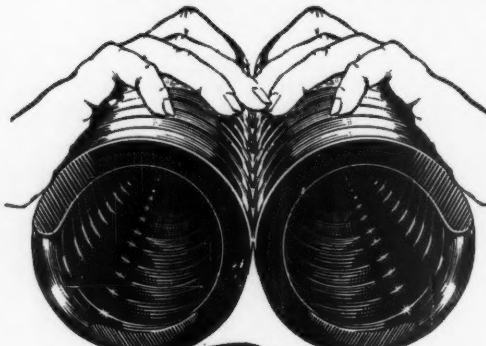


Looking in the right direction



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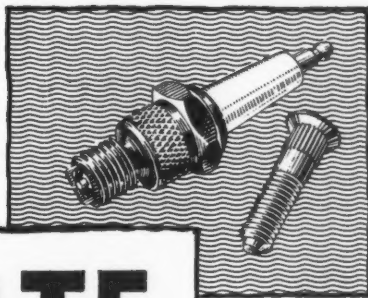

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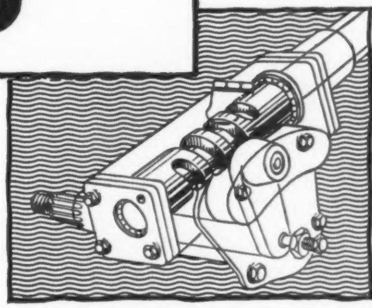

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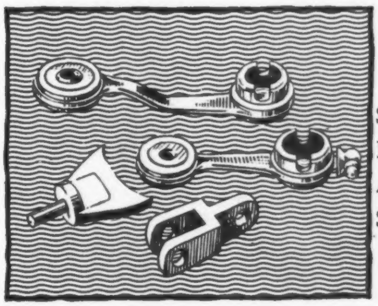

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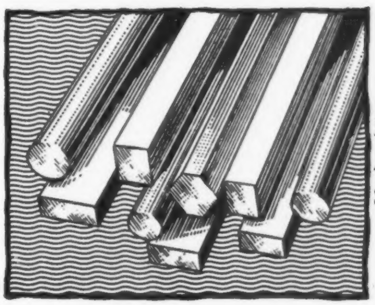

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